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### Errata

Volume 38, No. 4, August, 1945. Page 504, Obituary, Maurice Cole Tanquary. Line 3, Col. 1, should read: "died October 25, 1944" instead of 1945.

Volume 38, No. 3, June, 1945, page 403, note by S. W. Frost. *Sterictophora* should read *Stictocephala*.

### Notice

**The Entomological Society of America and The CENTRAL STATES BRANCH of the A.A.E.E. will meet with the American Association for the Advancement of Science, in St. Louis on March 27, 28, and 29, 1946. Headquarters for the entomological groups will be in the Hotel Jefferson.**

JOURNAL OF ECONOMIC ENTOMOLOGY
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Vol. 38 December, 1945 No. 6

# Crop Rotations and Cultural Practices as Related to Wireworm Control in Idaho[1,2]

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Field-plot studies to evaluate various crop rotations and cultural practices with reference to the control of wireworms under irrigated-farming conditions were carried on at Parma, in southwestern Idaho, during the years 1931–42. A preliminary report covering the years 1931–34 has been published (Shirck & Lanchester 1936). Since the investigations in Idaho have been terminated, the present paper is intended to furnish a complete report on these crop-rotation studies.

In the preliminary report it was pointed out that red clover was associated with large increases in wireworm populations, but that alfalfa tended to prevent rapid population increases. No increases were noted under 4 years of grass sod. Wireworm numbers remained stationary for the first 4 years of clean-cultivated truck crops. Drying out the soil[4] by growing wheat without irrigation gave mathematically significant reductions in wireworm populations in one season, provided the soil remained dry for a prolonged period. Some crops, notably potatoes and sugar beets grown for seed, were found to stimulate development of wireworm adults, whereas very few adults were produced in alfalfa or grass sod.

Two field-plot experiments were conducted: (1) For comparison of various crop rotations with respect to their effect on wireworms, and (2) for more intensive study of population trends under a single rotation of whatever type was found to be satisfactory for wireworm control. A study of supplemental cultural practices as affecting wireworms was made in connection with these field-plot experiments. Additional data on wireworm-population trends as related to crop sequences were obtained from a survey of fields carried on during 1940–42.

METHODS.—The first experiment consisted of three replicates of the comparison of six crop rotations. The arrangement of the $\frac{1}{6}$-acre plots was similar to randomized blocks, but some of the requirements for randomization were not met. The second experiment consisted of four replicates, in randomized blocks, of the comparison of four slight modifications of a single-crop rotation, grown on plots having an average size of $1\frac{1}{4}$ acres. Except for differences in irrigation, the plots were given the same cultivation and care, so far as the nature of the crops would allow. Some of the plots were left unirrigated at times to reduce wireworm infestations by soil drying. These plots were surrounded by levees to prevent accidental entry of water when adjoining plots were irrigated.

The wireworm infestation was determined by either sifting or washing a random sample of soil from each plot and counting the number of wireworms obtained. Each soil sample was composed of 20 or more sampling units taken at random from the plot by one of the sampling devices described by Jones (1937). Except when special samples were taken to obtain the first-year wireworms, the soil was sifted with the motor-driven soil-sifting machine described by Lane and Shirck (1936). In experiment 1 each unit

[1] The sugar-beet wireworm, *Limonius californicus* (Mann.), was the species principally encountered in these studies.

[2] In cooperation with the Idaho Agricultural Experiment Station.

[3] These studies were conducted under the direction of M. C. Lane, to whom acknowledgments are due for his suggestions and guidance. The writer is indebted to W. C. Cook for several suggestions, which were found helpful in writing this paper.

[4] Soil drying was suggested by ecological experiments conducted in the field and in the laboratory by E. W. Jones and K. E. Gibson, of the Walla Walla, Wash., laboratory. These experiments, as yet unpublished except as referred to by M. C. Lane in U. S. Dept. Agr. Farmers' Bul. 1866, showed that there is little doubt that soil humidity is a limiting environmental factor for wireworms. The maintenance of the normal water balance of wireworms is possible only in a saturated atmosphere. Tests in the Prosser and Walla Walla districts of Washington, showed that in sandy-loam soils drying was effective in destroying the eggs, larvae, and pupae of wireworms.

Table 1.—Wireworm populations following different crops under normal irrigation in crop-rotation experiment 1, 1931–37.

| Rotation and Year | Crop | Number of Wireworms per Square Foot in— | | | Average, All Plots |
|---|---|---|---|---|---|
| | | Plot 1 | Plot 2 | Plot 3 | |
| 1 1931 | Alfalfa | 0.7 | 1.1 | 1.0 | 0.9 |
| 1932 | Alfalfa | 1.1 | .8 | 1.3 | 1.1 |
| 1933 | Alfalfa | 1.1 | 3.2 | 2.1 | 2.1 |
| 1934 | Alfalfa | 2.5 | 2.5 | 2.9 | 2.6 |
| 1935 | Potatoes | 2.6 | 2.7 | 4.0 | 3.1 |
| 1936 | Sweet corn | 4.7 | 4.5 | 5.2 | 4.8 |
| 1937 | Beans | 4.1 | 1.7 | 2.3 | 2.7 |
| 2 1931 | Potatoes | .8 | 1.8 | .5 | 1.0 |
| 1932 | Alfalfa | .9 | 2.1 | .8 | 1.3 |
| 1933 | Alfalfa | 2.5 | 3.3 | 1.9 | 2.6 |
| 1934 | Alfalfa | 2.5 | 2.6 | 3.0 | 2.7 |
| 1935 | Alfalfa | [1].4 | [1].6 | [1]1.1 | .7 |
| 1936 | Potatoes | 1.3 | 2.5 | 2.6 | 2.1 |
| 1937 | Potatoes | 3.4 | 1.4 | 2.9 | 2.6 |
| 3 1931 | Red clover | 1.3 | [3]8.1 | 1.6 | 1.5 |
| 1932 | Red clover | 5.2 | [3]6.6 | 3.2 | 4.2 |
| 1933 | Sudan grass | [3]19.2 | [2,3]11.7 | [3]11.2 | 15.2 |
| 1934 | Wheat | [1]7.1 | [1,3]4.8 | [1]4.8 | 6.0 |
| 1935 | Sweetclover | 6.9 | [3]4.9 | 6.4 | 6.6 |
| 1936 | Potatoes | 8.4 | [3]6.5 | 10.0 | 9.2 |
| 1937 | Wheat | 7.6 | [3]2.4 | 7.0 | 7.3 |
| 4 1931 | Red clover | 3.0 | 1.4 | 1.5 | 2.0 |
| 1932 | Red clover | 5.8 | 3.7 | 3.4 | 4.3 |
| 1933 | Wheat | [3]7.4 | [3]16.8 | [3]5.1 | 9.8 |
| 1934 | Potatoes | 6.0 | 9.6 | 6.6 | 7.4 |
| 1935 | Alfalfa | 5.4 | 7.7 | 4.4 | 5.8 |
| 1936 | Alfalfa | 3.3 | 2.8 | 3.0 | 3.0 |
| 1937 | Alfalfa | 1.8 | 2.1 | 2.7 | 2.2 |
| 5 1931 | Truck crops | [3]5.4 | 3.9 | 1.3 | 2.6 |
| 1932 | Potatoes | [3]5.0 | 3.0 | .7 | 1.9 |
| 1933 | Wheat | [2,4]4.5 | [3]3.4 | [4]1.4 | 2.4 |
| 1934 | Sweet corn | [3]4.3 | 6.9 | 2.8 | 4.9 |
| 1935 | Peas | [3]5.0 | 5.8 | 2.8 | 4.3 |
| 1936 | Beans | [3]5.2 | 7.6 | 3.7 | 5.7 |
| 1937 | Sweet corn | [3]2.4 | 3.8 | 2.9 | 3.4 |
| 6 1931 | Pasture | [3]6.4 | 2.4 | 2.3 | 2.4 |
| 1932 | Pasture | [3]5.4 | 2.0 | 1.4 | 1.7 |
| 1933 | Pasture | [3]4.8 | 1.5 | 1.7 | 1.6 |
| 1934 | Pasture | [3]3.4 | 1.9 | 1.9 | 1.9 |
| 1935 | Potatoes | [3]4.1 | 4.8 | 3.4 | 4.1 |
| 1936 | Peas | [3]2.1 | 4.6 | 2.8 | 3.7 |
| 1937 | Pasture | [3]2.4 | 3.7 | 2.4 | 3.1 |

[1] Not irrigated.
[2] Values not included in averages because the plots were in red clover, rather than onions, prior to the beginning of the experiment.
[3] Irrigated twice during the season.
[4] Irrigated once during the season.

of soil was 1 square foot in area and 18 inches deep, and 25 units were taken from each plot at each sampling. In the regular samples during the remainder of the investigations at least 20 sampling units one-fourth square foot in area and 15 inches deep were taken with the post-hole auger. For counts of the first-year wireworms, each special sample consisted of 50 units each of one-sixteenth-square-foot of soil, and these samples were washed through fine sieves.

The infestation counts given above were made either in the fall, when larvae of the current year's brood had reached their maximum growth for the season and adults were present in the soil, or early in the spring before emergence of the adults.

Wireworm damage to potatoes was estimated by examining approximately 100

potatoes, taken at random from each plot just before the crop was harvested, and recording the percentage that contained feeding tunnels made by the wireworms.

EXPERIMENT 1.—The object of this experiment was to determine what rotations and cultural practices were favorable for decreasing wireworm populations and what practices seemed to favor their increase. As the studies proceeded, it became necessary to make changes in some of the rotations, to adapt them to the high wireworm populations that existed at the beginning in some of the plots or that developed during the experiment in others. In some cases these excessive populations made it impossible to grow the intended crops. Table 1 and figure 1 show the crops grown in this experiment.

It was surprising to observe slow but significant increases in wireworm populations in alfalfa in rotations 1 and 2 during the period 1931–34 (Fig. 1). General field observations in the Parma area indicated that populations ordinarily decreased rather than increased in alfalfa. Since it was found that relatively few wireworm adults matured in alfalfa each year, it was concluded that gravid females flying into the alfalfa plots must have been mainly responsible for the wireworm increases noted in rotations 1 and 2.

The most outstanding population fluctuations occurred in and following red clover. The peak infestations were noted in the crops immediately following red clover. It is believed, however, that the greatest increase in infestation in these plots took place while they were in red clover, before many of the wireworms had become large enough to be retained on the screens of the soil sifter. Special samples taken in the fall of 1932 and washed showed that the number of first-year larvae per square foot was 8.2 in the red clover plots, as compared with 3.5, 2.2, and 1.9 in the alfalfa, potato, and pasture plots, respectively.

Since red clover evidently caused populations to increase, its use was discontinued and sweetclover was substituted in rotation 3 and alfalfa in rotation 4. The wireworm populations did not increase so markedly following sweetclover as they did after red clover, but observations, both in the experimental plots and in other fields in the Parma area, indicated that there was a tendency for populations to build up immediately following sweetclover. After 1935 the population trend under alfalfa in rotation 4 was downward, in contrast with the fluctuating but high average population in rotation 3, where sweetclover was followed by potatoes and wheat.

Judging by the results obtained in experiment 1, it was concluded that rotations 1 and 2, which contained alfalfa, and rotation 6, consisting of 4 years of mixed-grass pasture followed by 2 years of cultivated crops, would be about equally safe in preventing excessive build-up of wireworm infestations. The growing of truck crops year after year, as in rotation 5,[1] eventually increased wireworm infestations and was, moreover, undesirable from the standpoint of maintaining soil fertility. Red clover and sweetclover were found to be unsafe for inclusion in truck-crop rotations, because of the increase in wireworm populations following their use.

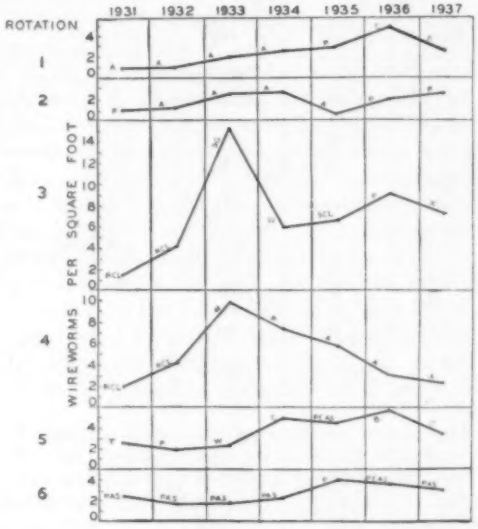


FIG. 1.—Annual trends in wireworm populations observed under six crop rotations at Parma, Idaho, 1931–37. Populations are shown for the close of each season under the following crops: Alfalfa (*A*), beans (*B*), corn (*C*), potatoes (*P*), peas; pasture (*Pas*), red clover (*Rcl*), Sudan grass (*SG*), sweetclover (*Scl*), mixed truck crops (*T*), wheat (*W*).

EXPERIMENT 2.—This experiment was designed as a somewhat intensive study of wireworm-population trends under a single-crop rotation. The rotation used

[1] Wheat, with limited amounts of irrigation water supplied, was grown in this rotation in 1933 in an attempt to reduce wireworm infestations by the method of soil drying.

was as follows: First to fourth years, alfalfa; fifth year, early potatoes; sixth year, corn or sugar beets; seventh year, wheat. The results of experiment 1 had indicated that a rotation of this type would be reasonably satisfactory from the viewpoint of avoiding excessively high wireworm populations, and would provide a safe legume crop for maintenance of soil fertility. Opportunities were provided for plowing early in August for control of pupae, following the harvest of early potatoes and wheat. Previous experiments (Shirck 1936) had shown that most of the pupae could be killed by plowing during the first week of August.

Observations made during 1938–41 (Shirck 1942) showed that many gravid females of the sugar-beet wireworm flew, and when collected from the air they contained, on an average, about 50 per cent of their eggs. It had also been observed in experiment 1 that significant population increases occurred in many plots in which the adult populations preceding the larval increases were negligible. It was concluded that the plot populations in experiment 1 tended to be equalized each year as a result of these beetle migrations, and that any possible beneficial effects which the various rotations may have had were thus in part obscured. In experiment 2 the plot size was increased to a minimum of 1.25 acres, in order to lessen the effect of beetle migrations and thus to restrict the annual influx of wireworms in a given plot to the progeny of adults that had developed in the same plot.

Three fields with a total area of 20 acres were used for this experiment. Wheat and alfalfa were growing in these fields when thel and was taken over for wireworm studies in the fall of 1937. Blocks 1 and 2, therefore, had to be started in the seventh

**Table 2.—Wireworm populations following different crops under normal irrigation in crop-rotation experiment 2, 1937–42.**

| Block | Plot | Average Number of Wireworms per Square Foot | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1937 | 1938 | 1939 | 1940 | 1941 | 1942 |
| 1 | | Wheat | Alfalfa | Alfalfa | Alfalfa | Alfalfa | Potatoes |
| | 1 | 5.0 | 4.8 | 3.1 | 2.4 | [1]2.2 | 0.6 |
| | 2 | 5.8 | 4.5 | 5.1 | 2.2 | 2.0 | 1.2 |
| | 3 | 7.0 | 5.6 | 4.7 | 2.6 | 2.2 | 1.2 |
| | 4 | 6.7 | 7.9 | 5.6 | 3.4 | [1]1.0 | 1.4 |
| | Average | 6.1 | 5.7 | 4.6 | 2.7 | 1.9 | 1.1 |
| 2 | | Wheat | Alfalfa | Alfalfa | Alfalfa | Alfalfa | Potatoes |
| | 5 | 10.1 | 6.1 | 4.2 | 2.3 | 2.2 | 1.8 |
| | 6 | 10.1 | 7.1 | 5.1 | 3.4 | [1]1.6 | 1.6 |
| | 7 | 10.1 | 5.7 | 4.3 | 1.9 | [1]1.0 | 2.4 |
| | 8 | 10.3 | 6.2 | 3.3 | 3.0 | 1.8 | 1.2 |
| | Average | 10.2 | 6.3 | 4.2 | 2.7 | 1.7 | 1.8 |
| 3 | | Alfalfa | Alfalfa | Potatoes | Corn or Sugar beets | Wheat | Alfalfa |
| | 9 | 1.1 | 1.0 | 0.8 | [2]0.8 | 0.6 | 0.2 |
| | 10 | 1.4 | 1.4 | 2.1 | [3].9 | 2.4 | .6 |
| | 11 | 2.2 | 1.1 | .4 | [3].4 | .0 | .0 |
| | 12 | 1.5 | 1.2 | 1.3 | [2]1.4 | 1.2 | .4 |
| | Average | 1.5 | 1.2 | 1.2 | .9 | 1.0 | .3 |
| 4 | | Alfalfa | Potatoes | Corn or Sugar beets | Wheat | Alfalfa | Alfalfa |
| | 13 | 1.5 | 1.6 | [3]0.7 | 1.6 | 1.0 | 0.8 |
| | 14 | 1.6 | 1.5 | [3]1.6 | .9 | 1.0 | .0 |
| | 15 | .8 | 1.2 | [2]1.7 | .9 | 2.8 | .2 |
| | 16 | 3.3 | 2.4 | [3]2.4 | 1.1 | 2.0 | .2 |
| | Average | 1.8 | 1.7 | 1.6 | 1.1 | 1.7 | .3 |

[1] Alfalfa not irrigated during the season.
[2] Corn.
[3] Sugar beets.

year of the rotation, block 3 in the third year, and block 4 in the fourth year. Special features of the experiment included soil drying in the last alfalfa year in certain plots, plowing early in August to destroy wireworm pupae, and growing corn and sugar beets simultaneously in the same block to compare the effects of these two crops on wireworms.

The comparison between corn and sugar beets was not made in enough cases to give conclusive results. It will be seen, however, by comparing populations (Table 2) before and after these crops

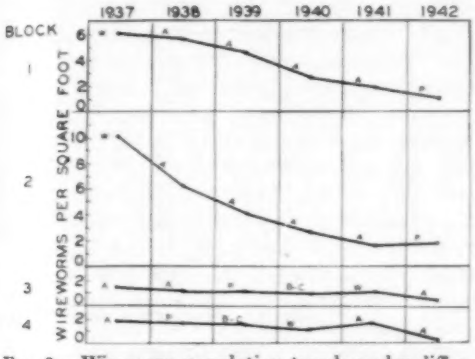


FIG. 2.—Wireworm-population trends under different phases of a 7-year crop rotation consisting of alfalfa (*A*), first 4 years; early potatoes (*P*), fifth year; corn (*C*) or sugar beets (*B*), sixth year; and wheat (*W*), seventh year.

were grown, that populations tended to increase after corn and to decrease slightly after beets. On the whole, the curves of figure 2 show that there were only slight fluctuations and no definite population trends in the fifth to seventh years of the rotation (Blocks 3 and 4) when annual crops succeeded alfalfa. Significant downward trends in wireworm populations were noted in alfalfa in blocks 1 and 2. The crop history of these blocks had included red clover for many years before the beginning of this experiment, which may explain the high wireworm populations found there in 1937. Except where specified, the crops received normal irrigation.

SOIL DRYING AS AN AID TO WIREWORM CONTROL.—In experiment 1 Sudan grass in rotation C and wheat in rotation E were grown with limited amounts of irrigation water in 1933 to determine whether the soil would become dry enough to cause any reduction in wireworm populations. These crops were irrigated only once or twice (Table 1), being given barely enough water to mature a partial crop of grain.[1] The wireworm populations were not reduced by this partial drying, but tended to increase in spite of it. When wheat was grown entirely without irrigation in rotation C in 1934, however, the wireworm population per square foot dropped from 15.2 to 6.0. Soil drying by omitting irrigations for a full season was tried with alfalfa in rotation B in 1935 and resulted in a decrease of 2.0 wireworms per square foot. No corresponding drop took place in the infestation in rotation A, where alfalfa in its last year received the normal number of irrigations (Fig. 1).

A soil-drying test was also made in experiment 2. The results, as summarized in table 3, show a greater reduction of wireworms in the plots not irrigated in 1941 than in the plots that received normal irrigation, although the difference is not statistically significant. Furthermore, wireworm damage to potatoes grown the year following the soil drying was somewhat less in the plots that had been dried than in the irrigated plots. The alfalfa in the dried plots was not cut for hay in 1941, but was allowed to stand for seed production. A fair yield of seed was obtained, the value of which was equal to that of the hay that might have been harvested had the plots been irrigated.

**Table 3.—Wireworm populations before and after soil-drying test (experiment 2), and wireworm damage to potatoes grown the year after drying was practiced.**

| Irrigation in 1941 | Plot No. | Number of Wireworms per Square Foot on— | | | Percentage of Damaged Potatoes in 1942 |
|---|---|---|---|---|---|
| | | Alfalfa | | Potatoes | |
| | | 1940 | 1941 | 1942 | |
| None | 1 | 2.4 | 2.2 | 0.6 | 11.7 |
| | 4 | 3.4 | 1.0 | 1.4 | 22.1 |
| | 6 | 3.4 | 1.6 | 1.6 | 7.6 |
| | 7 | 1.9 | 1.0 | 2.4 | 19.7 |
| | Average | 2.8 | 1.5 | 1.4 | 15.4 |
| Normal | 2 | 2.2 | 2.0 | 1.2 | 36.5 |
| | 3 | 2.6 | 2.2 | 1.2 | 26.9 |
| | 5 | 2.3 | 2.2 | 1.8 | 8.2 |
| | 8 | 3.0 | 1.8 | 1.2 | 23.8 |
| | Average | 2.5 | 2.1 | 1.5 | 23.9 |

GENERAL SURVEY OF FIELDS.—Although the results indicated that the rotation used in experiment 2 might be

[1] In general, wheat and alfalfa in the Parma area are given at least three irrigations. Sudan grass is not commonly grown there, but was tried in these soil-drying tests because of its drought-resisting quality.

satisfactory from the viewpoint of cultural control of wireworms, it was surprising to note a tendency for wireworm populations to continue without significant change in crops that followed alfalfa (Fig. 2, blocks 3 and 4). This was contrary to what happened in experiment 1, where populations had increased when alfalfa was succeeded by annual crops (Fig. 1, rotations 1 and 2). In order to obtain further information on what population changes might be expected in crops that came after alfalfa in the rotation, 52 alfalfa fields were sampled for wireworms in the last alfalfa year, and the population counts were repeated annually after the next two crops in the same fields.

The results of this survey showed that the average wireworm population increased after alfalfa (Fig. 3 and Table 4) and remained significantly higher for the next 2 years. It will be seen from figure 3

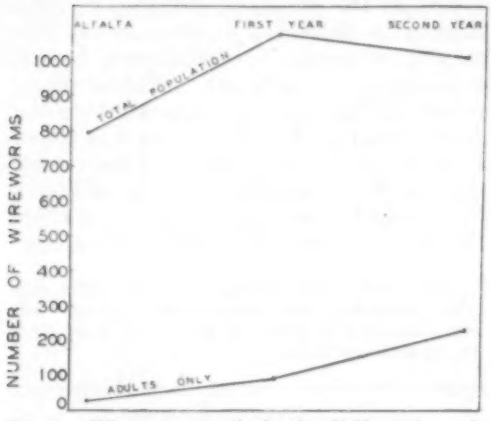


FIG. 3.—Wireworm population in alfalfa and trends in adult- and total-wireworm populations in the first 2 annual crops following alfalfa. Summary of records from 52 fields.

**Table 4.—Trend of wireworm populations in crops following alfalfa, 1940–42.**

| Field No. | Number of Wireworms in 10 Square Feet Following— | | |
|---|---|---|---|
| | Alfalfa | Corn | Small grain |
| 1 | 8 | 37 | 14 |
| 2 | 9 | 73 | 44 |
| 3 | 15 | 22 | 26 |
| 4 | 12 | 44 | 14 |
| 5 | 43 | 41 | 52 |
| 6 | 11 | 9 | 6 |
| 7 | 10 | 14 | 14 |
| 8 | 10 | 5 | 2 |
| 9 | 8 | 15 | 6 |
| 10 | 6 | 33 | 30 |
| 11 | 16 | 25 | 12 |
| 12 | 8 | 28 | 20 |
| 13 | 7 | 5 | 2 |
| Total | 163 | 351 | 242 |

**Table 4—(continued)**

| Field No. | Number of Wireworms in 10 Square Feet Following— | | |
|---|---|---|---|
| | Alfalfa | Sugar beets | Sugar beets |
| 14 | 9 | 9 | 18 |
| 15 | 23 | 20 | 32 |
| 16 | 13 | 23 | 2 |
| 17 | 29 | 15 | 16 |
| 18 | 6 | 2 | 0 |
| 19 | 7 | 4 | 2 |
| 20 | 16 | 27 | 38 |
| 21 | 20 | 11 | 20 |
| 22 | 2 | 7 | 6 |
| 23 | 13 | 12 | 28 |
| Total | 138 | 130 | 162 |
| | Alfalfa | Small grain | Small grain |
| 24 | 6 | 4 | 18 |
| 25 | 23 | 19 | 40 |
| 26 | 24 | 28 | 64 |
| 27 | 4 | 1 | 2 |
| 28 | 1 | 12 | 12 |
| 29 | 44 | 51 | 34 |
| 30 | 58 | 37 | 56 |
| 31 | 17 | 13 | 24 |
| 32 | 23 | 21 | 2 |
| 33 | 25 | 19 | 44 |
| Total | 225 | 205 | 296 |
| | Alfalfa | Row crops | Small grain |
| 34 | 10 | 4[1] | 4 |
| 35 | 8 | 19[1] | 20 |
| 36 | 38 | 28[1] | 16 |
| 37 | 5 | 4[2] | 2 |
| 38 | 13 | 11[2] | 6 |
| 39 | 9 | 33[2] | 16 |
| 40 | 2 | 12[2] | 6 |
| 41 | 26 | 26[2] | 28 |
| Total | 111 | 137 | 98 |
| | Alfalfa | Row crops | Row crops |
| 42 | 24 | 83[3] | 26[1] |
| 43 | 26 | 37[2] | 30[1] |
| 44 | 18 | 15[2] | 18[1] |
| 45 | 10 | 8[3] | 14[2] |
| 46 | 32 | 20[3] | 40[2] |
| 47 | 14 | 19[3] | 2[2] |
| 48 | 9 | 29[2] | 40[2] |
| 49 | 4 | 8[2] | 16[4] |
| 50 | 6 | 15[1] | 8[2] |
| 51 | 3 | 6[5] | 14[1] |
| 52 | 8 | 7[3] | 2[1] |
| Total | 154 | 247 | 210 |
| Grand total | 791 | 1,070 | 1,008 |
| Average per field | 15.27 | 20.58 | 19.38 |
| Increase over alfalfa | | 5.37±2.19 | 4.18±1.75 |

[1] Sugar beets.
[2] Potatoes.
[3] Corn.
[4] Lettuce.
[5] Radishes.

that the total wireworm populations leveled off in the second year, but the number of adults increased progressively. The more succulent foods available after alfalfa probably caused an acceleration in the development of the wireworm larvae, and the loosened soil condition due to the cultivation of annual crops may have favored the formation of pupal cells. The diversity of crops grown, particularly in fields 34–52, made it difficult to assess the effect of any particular crop or sequence of crops on the population trend. However, in fields 1 to 13, which were planted to corn following alfalfa, the increase in total number of wireworms from 163 to 351 was significant. The decrease to 242 when these fields were planted to small grains was also significant. Analysis showed that a significant average increase of $0.68 \pm 0.30$ wireworm per square foot took place in potatoes grown the first year following alfalfa, a sequence found in fields 37–41, 43, 44, 47–49; but in fields 14–23, where sugar beets were grown in the two years after alfalfa, there was no significant population change in either year. Thus, the general survey of fields showed that, although there was a wide variation between fields, potatoes or corn following alfalfa tended to increase wireworm populations, whereas sugar beets did not.

SEASONAL HISTORY AS RELATED TO CULTURAL CONTROL.—In southern Idaho the eggs of the sugar beet wireworm are laid during May, and most of them are hatched by the middle of June. Most of the wireworms remain small during their first season and are very susceptible to drying and starvation. Some natural mortality occurs during the second and third seasons but not so much as during the first season. Alfalfa as a crop has a tendency to keep the surface foot of soil in a dry and very compact condition, which, combined with the fact that alfalfa is a poor food for wireworms, is detrimental to wireworm growth and survival. Mature wireworms, usually in their third season, prepare to pupate early in July, pupation reaching a peak about August first. Plowing at this time, after early crops have been removed, has been shown by Shirck (1936) to kill most of the delicate pupae and the new adults.

Wireworms that survive their first season over winter from 3 to 24 inches deep in the soil and are seldom affected by freezing temperatures at this depth. The adults that develop from pupae in the summer remain in the soil throughout the winter, and are not affected by the winter temperatures common in southern Idaho. During their flight period in April and May, the adults are subject to depletion by predators, but they usually mate successfully and deposit their eggs in the soil of cultivated land.

SUMMARY AND CONCLUSIONS.—Systematic studies were made at Parma, Idaho, of wireworm-population trends under different crop rotations. Under normal conditions changes in population were gradual from year to year, but excessive increases occurred in red clover fields. High wireworm populations in alfalfa decreased from year to year, and the decrease was accelerated by soil dryness in fields where the alfalfa was allowed to go an entire season without irrigation. A survey of 52 fields showed that in general wireworm populations increased in the first crop following alfalfa. This increase was mathematically significant for potatoes and corn. There was no significant population change in sugar beets grown for 2 years following alfalfa. The increase in adults in crops following alfalfa was more rapid than the general increase in wireworm populations. A relatively long crop rotation, in which the land is in alfalfa at least half the time, appears to offer the best opportunity for cultural control of wireworms.—10-20-45.

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# Concentration-Survival Time Relationship for Roaches Injected with Arsenicals

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In a previous paper (Yeager & Munson 1945) the authors described and discussed the concentration-survival time curves obtained when the American cockroach, *Periplaneta americana* (L.), and the oriental cockroach, *Blatta orientalis* L., were injected with sodium metarsenite. In that paper it was shown that certain attributes of these curves could be explained by assuming that the toxicity of this poison is dependent upon the formation of arsenite ions. The authors presented equations which permitted good agreement between calculated and experimental survival times. An extension of that work is reported in the present paper, wherein experiments and equations previously reported retain the numbers previously assigned to them and additional experiments and equations are given following numbers.

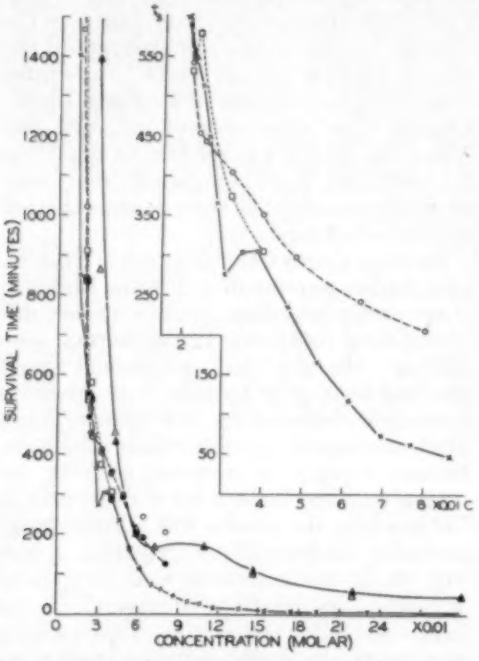


FIG. 1.—Parts of concentration-survival time curves of insects injected with arsenicals, from experiments 1 (x), 6 (□ ■), and 7 (○ ●) with cockroaches, and experiment 9 (△ ▲), with yellow mealworm larvae; x, □, ○, and △ represent observed and ■, ●, and ▲ calculated (equation 14) survival times.

METHODS.—The experimental procedures were essentially the same as those described in the previous paper, to which the reader may refer for details of technique. Certain data from experiment 1 from the previous paper are given here in table 1 for comparison. Table 1 also indicates the nature of the additional experiments 6 to 9, herein described. For convenience, in this paper the sodium monohydrogen orthoarsenate will be referred to as sodium arsenate, and the colloidal lead arsenate as lead arsenate. Experiment 1 is fully described in the previous paper. In experiments 6 to 8, as in the former study, large nymphs of the roach *Periplaneta americana* were used. Experiment 9, in which the yellow mealworm, or larva of *Tenebrio molitor* L., was used, was carried out in connection with another investigation, but is included here for comparison.

The greater volume (0.020 ml. per gram of body weight) of poison solution (or suspension) injected during experiment 7 was used to increase dosage without having a fine suspension that appeared in the 0.04006 M solution. In experiment 8 the dosage was increased by doubling the volume injected to extend the range of the concentration of poison in the hemolymph.

An insect injected with 0.020 ml. per gram of body weight of a poison having molar concentration $c$ would receive the same number of gram moles of poison per gram of body weight as an insect injected with 0.010 ml. per gram of body weight of concentration $2c$. Although the number of gram moles per unit of body weight would be the same in the two cases, the bloods of the two insects may contain slightly different concentrations of the poison, because of the different volumes of solvent (saline) injected with the poison. There is reason to consider the blood volume of *Periplaneta americana* to be of the order of 0.1 ml. per gram of body weight. If each roach had a blood volume of 0.1 ml. per gram of body weight, the difference in concentration of poison in the blood due to the saline injected would be of the

**Table 1.—Comparison of experiments in which cockroach nymphs and mealworm larvae were injected with arsenicals.**

| Experiment No. | Insects Used | | Solution Injected: Solute (Insecticide) | Solution Injected: Solvent | Solution Injected: Volume per Gram of Body Weight | Limits of—: Region of Inflection | Limits of—: Critical Zone |
|---|---|---|---|---|---|---|---|
| | | *Number* | | | *Milliliters* | *Molar* | *Molar* |
| 1 | Cockroach | 390 | Sodium metarsenite ($NaAsO_2$) | 1.34% NaCl[1] | 0.010 | 0.03846–.03076 | 0.01538–.007692 |
| 6 | Cockroach | 150 | Sodium monohydrogen orthoarsenate ($Na_2HAsO_4 \cdot 7H_2O$) | 1.10% NaCl | .010 | .02404–.02244 | .02003–.009615 |
| 7 | Cockroach | 170 | Sodium monohydrogen orthoarsenate ($Na_2HAsO_4 \cdot 7H_2O$) | 1.10% NaCl | .020 | .02564–.02404 | .01923–.009615 |
| 8 | Cockroach | 151 | Colloidal lead arsenate ($PbHAsO_4$) | Complex saline[2] | .020 | — | .1729 –.02881 |
| 9 | Mealworm | 122 | Sodium metarsenite | 1.1% NaCl | .019 | .1096 –.07307 | .01461–.007307 |

[1] Per cent = grams per 100 ml.
[2] NaCl 10.93, KCl 1.57, $CaCl_2$ 0.85, $MgCl_2$ 0.17 gram per liter.

order of 10 per cent, which may be considered not greater than the total experimental error. Thus, within experimental error, the blood concentrations of poison in experiments 7 and 8 may be put on a common basis with those in experiments 1 and 6 by multiplying all the injected concentrations by 0.10 and then, in experiments 7 and 8, multiplying these values by 2. This was done in calculating the values plotted in figure 2. The injected dosages, however, are equated by multiplying the concentrations by the number of unit volumes injected. Thus, taking 0.010 ml. per gram of body weight as unit volume, the dosages in experiments 7 and 8 are multiplied by 2.0 and those in experiment 9 are multiplied by 1.9 to make them comparable with those in experiments 1 and 6. In this way the results of the different experiments were reduced to the same scale for comparison.

In experiment 9 the mealworms were matched for size by eye against a standard larva of chosen weight. Eleven groups of 10 to 12 larvae each were selected in this manner. Subsequently each larva was weighed individually. The larvae of one of these groups were injected with 1.1 per cent saline and were used for controls. The larvae of the other groups were injected with sodium metarsenite in the saline, each group receiving a different concentration of poison. Injection was by means of a hypodermic syringe held in a Dutky-Fest microinjector (Dutky 1942), which delivered 0.00232 ml. at a single depression of a key.[1] Each larva received this volume regardless of weight; therefore, these injections were not as quantitative as those of the other experiments, although the ranges of body weights in the groups of experiment 9 were not very different (Table 4). To reduce hemorrhage and trauma, the larvae were chilled to immobility just before being injected. The needle was inserted through an intersegmental membrane in the dorsolateral region about the middle of the body. On the average each larva received 0.019 ml. per gram of body weight.

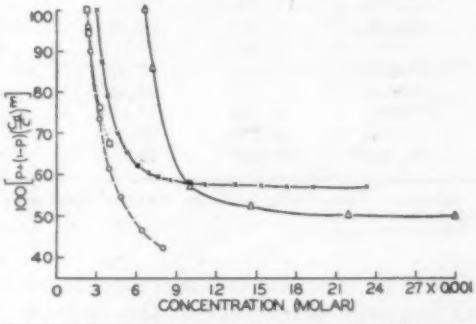


FIG. 2.—Curves interpreted as percentage dissociation curves for sodium metarsenite (x, expt. 1) and sodium arsenate (□, expt. 6; ○, expt. 7) in the blood of injected roaches, and for sodium metarsenite (△, expt. 9) in the blood of the mealworm.

The sodium metarsenite ($NaAsO_2$) and the sodium arsenate ($Na_2HAsO_4 \cdot 7H_2O$) were of c.p. grade. Because a c.p. grade of lead arsenate in saline did not make a suitable solution or suspension, a commercial, micronized colloidal lead arsenate sold in the form of a viscous paste was used. The manufacturer's analysis indicated this to be dilead orthoarsenate ($PbHAsO_4$). Originally it contained not

[1] The particular apparatus used here was borrowed from the laboratory of the U. S. Bureau of Entomology and Plant Quarantine at Moorestown, N. J., where it had been developed for use in Japanese beetle control.

**Table 2.—Observed and calculated survival times of cockroach nymphs injected with sodium arsenate. (Ten insects were injected at each concentration except as indicated by footnote 2.)**

| Concentration of Insecticide Injected | Experiment 6 | | | Experiment 7 | | |
|---|---|---|---|---|---|---|
| | Observed Means | | Calculated by Equation (14) to Fit Harmonic Mean | Observed Means | | Calculated by Equation (14) to Fit Harmonic Mean |
| | Arithmetic[1] | Harmonic | | Arithmetic[1] | Harmonic | |
| *Molar* | *Minutes* | *Minutes* | *Minutes* | *Minutes* | *Minutes* | *Minutes* |
| 0.08012 | — | — | — | 207 | 205 | 125 |
| .06410 | — | — | — | 247 | 242 | 190 |
| .04807 | — | — | — | 301 | 298 | 291 |
| .04006 | 306 | 305 | 288 | 363 | 351 | 356 |
| .03205 | 378 | 375 | 410 | 412 | 405 | 412 |
| .02564 | — | — | — | 452 | 444 | 449 |
| .02404 | 614 | 580 | 540 | 496 | 454 | 451 |
| .02244 | 615 | 534 | 556 | 611 | 542 | 495 |
| .02003 | 4,931<br>1,079 (9) | 911 | 839 | — | — | — |
| .01923 | — | — | — | 5,640<br>1,387 (9) | 1,021 | 847 |
| .01602 | 6,977<br>2,061 (8) | 1,860 | 1,954 | 11,063<br>1,949 (8) | 1,469 | 1,636 |
| .01522 | 15,554<br>3,705 (7) | 3,248 | 2,391 | — | — | — |
| [2].01442 | 19,433<br>4,309 (6) | 3,916 | 3,141 | 20,701<br>4,742 (6) | 2,221 | 2,423 |
| .01282 | 35,424<br>12,720 (3) | 13,360 | 4,830 | 20,450<br>6,808 (6) | 3,062 | 3,807 |
| .01122 | 36,864<br>17,280 (4) | 18,100 | 8,642 | — | — | — |
| .009615 | 37,872<br>18,000 (5) | 22,095 | 17,853 | 26,504<br>11,679 (5) | 15,085 | 12,440 |
| .006410 | 40,032 | 37,700 | 191,291 | 42,048 | 41,175 | 90,799 |
| .003205 | 47,120 | 43,690 | ∞ | 45,288 | 44,335 | 417,875,700 |
| .001602 | 49,192 | 45,030 | | 47,348 | 43,825 | ∞ |
| .0008012 | 40,752 | 38,450 | | 41,184 | 39,000 | |
| 1.1% Nacl | 39,600 | 39,100 | | 46,080 | 40,750 | |

[1] Alternative values are the means for the lower modal groups in the critical zone. The number of insects in each lower group i given in parentheses.
[2] Only 9 insects injected.

more than 35 per cent of inert ingredients. An unknown percentage of the inert ingredients was lost by evaporation of the stock supply and 57 per cent more was removed by desiccation over calcium chloride ($CaCl_2$). After desiccation the material was suspended in the complex saline (Table 1). The error in concentration of the lead arsenate caused by the inert ingredients and the drying of the stock supply could not have exceeded 15 per cent, and probably amounted to only a few per cent. The results of experiment 8 are to be regarded as only approximate.

After injection, the roaches were observed at intervals until their failure to respond to mechanical stimuli indicated that they were dead. Failure to respond to mechanical stimulation is an arbitrary end point for the determination of death but it is convenient and adequate for these studies of arsenical poisoning, in which the lethally poisoned insects showed little or no tendency to recover. The symptoms of toxicity were recorded according to the following symbols:

*A* The injected insect appears no different from one not injected.

*A*− The insect is like *A*, except less active. It can recover equilibrium, if turned on its back, and can walk.

*S* The insect appears definitely affected. Although it shows recovery reflexes, it cannot recover equilibrium; when righted, it can stand and walk; and when placed on its back, it can move its legs, other appendages, and body fairly vigorously.

*L* The insect does not show recovery reflexes and cannot recover equilibrium, but can move most or all of its appendages and its body fairly vigorously.

$M_1$ The insect differs from *L* by being more feeble. It shows only slight or weak movements of appendages and body.

$M_2$ The insect is almost, but not quite, com-

pletely immoble; only very slight localized movement in body or appendages may take place occasionally, or possibly an infrequent very slight twitch of the whole body; mechanical stimulation is usually necessary to elicit these movements.

*D* The insect shows no response to mechanical stimulus and is considered dead.

Symptoms were recorded also in the work reported previously (Yeager & Munson 1945) but were not included in that paper because it was, at that time, the intention of the authors to discuss them in this one.

RESULTS.—The concentrations and survival times (arithmetic and harmonic means) for experiments 6 and 7 are given in table 2. Part of the curve obtained by plotting survival time against concentration is shown in figure 1 for experiments 1, 6, and 7. The sodium arsenate curves are of the same type as those reported previously for sodium metarsenite; that is, they simulate rectangular hyperbolas, exhibit regions of inflection at about the same part of the concentration range as the sodium metarsenite curves, and also have critical zones in about the same regions (Fig. 1 and Tables 1 and 2).

The colloidal lead arsenate curve (Expt. 8) is also hyperbolic but exhibits no region of inflection, as do the sodium arsenite and sodium arsenate curves. The plot of this curve is not shown, but the survival times are given in table 3. A critical zone is indicated by the great divergence of the harmonic and arithmetic means corresponding to the lower concentrations (Tables 1 and 3).

The concentration-survival time curve from experiment 9 on *Tenebrio molitor* also is hyperbolic, exhibits a region of inflection, and has a critical zone (Tables 1 and 4, and Fig. 1).

With respect to symptoms of toxicity, it is characteristic of arsenic poisoning that a poisoned insect passes steadily downward through the successive symptomatic stages to death, without apparent interludes of recovery (either partial or complete) and relapse. After injection an insect usually shows activity above normal, but for only a few seconds. When survival time exceeds about 30 minutes, several injected insects can be observed through all the symptomatic stages, but this cannot be done so readily when survival times are shorter. The progress of poisoning is illustrated by the scheme in figure 3, discussed later.

**Table 3.—Observed and calculated survival times of cockroach nymphs injected with lead arsenate, experiment 8.**

| Concentration of Insecticide Injected | Survival Time: Observed Means | | Survival Time: Calculated to Fit Harmonic Means | | "Per Cent Dissociation" Calculated from $100\left[p+(1-p)\left(\frac{c_d}{c}\right)^m\right]$ in Equation 14 |
|---|---|---|---|---|---|
| | Harmonic | Arithmetic | By Equation 14 | By Equation 24 | |
| *Molar* | *Minutes* | *Minutes* | *Minutes* | *Minutes* | |
| 1.440 | 237 | 240 | 193 | 173 | 2.13 |
| 1.152 | 229 | 232 | 234 | 216 | 2.51 |
| .8642 | 308 | 326 | 302 | 288 | 3.10 |
| .5762 | 325 | 340 | 436 | 432 | 4.19 |
| .2881 | 789 | 862 | 832 | 864 | 7.00 |
| .2305 | 1,083 | 6,546 | 1,032 | 1,080 | 8.26 |
| .1729 | 1,560 | 17,732 | 1,369 | 1,439 | 10.22 |
| .1152 | 2,075 | 21,843 | 2,042 | 2,160 | 13.81 |
| .05762 | 3,261 | 26,820 | 4,281 | 4,319 | 23.06 |
| .02881 | 13,275 | 37,310 | 9,424 | 8,638 | 38.54 |
| Complex saline | 32,430 | 45,168 | ∞ | 17,281 | — |

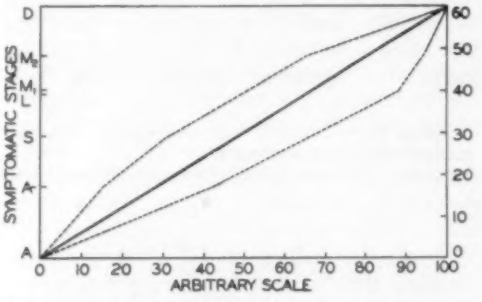


FIG. 3.—Relation between time after injection and toxic symptoms of roaches injected with the arsenical poisons. Symptomatic stages on vertical axis. Arbitrary scale on horizontal axis. $A=0$, $A-=17$, $S=29$, $L=38$, $M_1=40$, $M_2=48$, and $D=60$.

ANALYSIS AND DISCUSSION OF RESULTS.—In the previous paper equations were given for fitting the curves obtained when roaches were injected with different concentrations of sodium metarsenite; of those, equations 14 and 19 will be used here. Equation 14 may be expressed as

$$t_s - a = \frac{K}{n-1}\left\{\frac{1}{\left(\left[pc + c(1-p)\left(\frac{c_d}{c}\right)^m\right] - c_0\right)^{n-1}}\right\}$$

and equation 19 as

$$t_s - a = \frac{K}{n-1}\left\{\frac{1}{\left[pc + c(1-p)\left(\frac{c_d}{c}\right)^m\right]^{n-1}}\right\}.$$

Equation 19 differs from equation 14 only in that $c_0$ is equated to zero and drops out of the expression. The previous paper should be referred to for a complete discussion of the equations and underlying theory.

The survival times of roaches calculated by equation 14 for experiments 6 and 7 are given in table 2. Part of the concentration-survival time curves (calculated and observed) for roaches and mealworms are shown in figure 1. The values of the constants that had to be used to get these fits are shown in table 5. The observed and calculated survival times for the two highest concentrations used in experiment 7 are not in good agreement. With this exception, the calculated and observed survival times are in good agreement.

Although the curves of experiments 6 and 7 cross (Fig. 1), at concentrations below the inflection they lie very close together and statistically (standard error of difference between corresponding mean survival times) are not significantly different. The constants (Table 5) that had to be used to get the fits to these two curves are very similar, the greatest difference being in the values for $p$ and for $m$ which, by interpretation, have to do with the rate of dissociation of the poison as its concentration in the blood becomes less. (In a sense, $p$ and $m$ are compensatory in the curve-fitting process.) Within experimental error, the difference in volume of saline (0.010 ml. per gram of body weight) injected in the two experiments had no

**Table 4.—Observed and calculated survival times of mealworm larvae injected with sodium metarsenite, experiment 9.**

| Concentration of Insecticide Injected | Larvae | | | Survival Time | | | |
|---|---|---|---|---|---|---|---|
| | | Body Weight | | Harmonic Mean | | Arithmetic Mean | |
| | Injected | Range | Average | Observed[1] | Calculated by Equation 19 | Observed[1] | Calculated by Equation 19 |
| *Molar* | *Number* | *Milligrams* | *Milligrams* | *Minutes* | *Minutes* | *Minutes* | *Minutes* |
| 0.2922 | 11 | 95–135 | 114 | 41 | 41 | 57 | 54 |
| .2193 | 12 | 105–135 | 119 | 45 | 55 | 54 | 73 |
| .1461 | 10 | 95–135 | 120 | 64 | 107 | 115 | 140 |
| | | | | 101 (8) | | 137 (8) | |
| .1096 | 11 | 105–135 | 121 | 169 | 169 | 246 | 222 |
| .07307 | 10 | 105–135 | 127 | 167 | 167 | 219 | 219 |
| .05844 | 10 | 95–135 | 117 | 211 | 201 | 376 | 263 |
| .04385 | 10 | 95–135 | 115 | 273 | 435 | 595 | 569 |
| | | | | 456 (9) | | | |
| .02922 | 11 | 105–125 | 115 | 862 | 1,398 | 1,191 | 1,827 |
| .01461 | 10 | 105–165 | 129 | 6,922 | 10,971 | 16,892 | 14,326 |
| .007307 | 12 | 105–155 | 128 | 17,565 | 87,210 | 43,440 | 113,875 |
| 1.1% Nacl | 12 | 105–145 | 132 | 36,385 | ∞ | 39,840 | ∞ |

[1] A number in parentheses is the number of insects on which the alternative survival time is based; that is, one or two larvae were excluded for reasons like those given previously by Yeager & Munson (1945). Otherwise, the mean values are for the number of insects injected.

significant effect on the results.

The sodium arsenate curves (Expts. 6 and 7) and the sodium metarsenite curve (Expt. 1) differ widely in the higher concentrations (Expt. 7), but as concentration decreases the curves approach each other more closely until they tend to coincide below their regions of inflection. When the differences between the mean survival times (arithmetic) for two closest corresponding concentrations of curves 1 and 7 were tested statistically (standard error of difference between the means), they were found to be significantly different at about 0.08 M. As concentration falls below this and the curves come closer together, the statistical difference becomes less until it disappears somewhere above their regions of inflection. In and below the regions of inflection, down to at least the upper part of their critical zones, the curves of experiments 1, 6, and 7 are not statistically different. Thus, the injected arsenate and metarsenite salts of sodium show a significant difference in toxicity only at concentrations considerably above their regions of inflection.

This relationship with respect to toxicity of sodium arsenate and sodium metarsenite receives a rational explanation on the basis of the dissociation hypothesis discussed by Yeager & Munson. According to this, toxicity of the arsenite and arsenate salts is dependent upon their formation of ions. At the highest equimolar total concentrations in the blood of the insect, the sodium metarsenite dissociates to a greater extent than does the sodium arsenate, the concentration of arsenite ions is greater than that of arsenate ions, and therefore the two poisons will cause survival times that are less for the arsenite than for the arsenate. As concentration decreases this difference will become less, until at the inflection of its curve each salt has become completely dissociated into ions or dissociated to the extent that, considering experimental error, the dissociation may be treated as complete. As concentration becomes still lower there no longer will be differences between the two curves due to differences in degree of dissociation of the two poisons. If the differences in the two poisons are due wholly or principally to the differences in their degree of dissociation, then their concentration-survival time curves should differ when the poisons are dissociated to different extents and should be the same when the poisons are completely dissociated. This is the way the curves of experiments 1 and 7 (and 1 and 6) behave, for in and below the region of inflection where, by hypothesis, the poisons should be completely dissociated, the curves virtually coincide, when allowance is made for experimental error. Thus in and below the region of inflection, equimolar concentrations of sodium metarsenite and sodium arsenate have the same toxicity within the limits of experimental error.

The concentration-survival time curve (Expt. 8) for the colloidal lead arsenate differs from the sodium arsenite and sodium arsenate curves in that it shows no region of inflection. Although the error involved in this experiment is somewhat greater, the following discussion will show that the results of experiment 8 are in agreement with those of the other experiments of this and the previous paper and that, according to the dissociation hypothesis, the colloidal lead arsenate curve need not be expected to exhibit a region of inflection. In summarizing the work of others on the chemical behavior of the acid lead arsenate ($PbHAsO_4$) Frear (1942, *pp. 22–24*) states that this com-

**Table 5.—Values of the constants used in calculating survival times of cockroaches and mealworms injected with arsenicals.**

| EXPERIMENT No. | $n$ | $K$ | $c_o$ | $a$ | $m$ | $c_d$ | $p$ | EQUATION |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 0.01080 | 0.007320 | 5 | 3 | 0.03090 | 0.57 | 14 |
| 6 | 4 | .01080 | .00375 | 5 | 1.8 | .02244 | .50 | 14 |
| 7 | 4 | .01080 | .003000 | 5 | 1.5 | .023055 | .32 | 14 |
| 8 | 4 | .01080 | .003846 | 5 | .74074 | .007955 | 0 | 14 |
| 8 | 4 | .01140 | 0 | 5 | .66667 | .003907 | 0 | [1]19 |
| 9 | 4 | .1024 | 0 | 30 | 4 | .067355 | .50 | 19 |

[1] Same as equation 24, where $h = 248.8$ and $q = 1$.

pound hydrolyzes according to the equation, 5 $PbHAsO_4+HOH \rightleftarrows Pb_4(PbOH)(AsO_4)_3+2H_3AsO_4$; that the reaction reaches equilibrium while the concentration of the arsenic acid is very low but may proceed to completion if the soluble product is removed; that the lead arsenate may be more soluble in sodium chloride and sodium carbonate solutions than in distilled water; and that it may tend to change over to other forms at pH values less than 2 or greater than 5. Although the lead arsenate may be slightly more soluble in roach blood, which normally has a pH greater than 5 (Glaser 1925) and might contain some sodium carbonate, complete solution and complete dissociation of the colloidal lead arsenate in the insect blood would occur at concentrations so low that they would be sublethal. Inasmuch as complete dissociation of the poison would take place only in sublethal concentrations, no region of inflection would appear in the concentration-survival time curve. This is in accordance with the fact that no inflection does occur in the observed concentration-survival time curve of experiment 8, when allowance is made for the experimental error involved in the injection of the less readily controlled lead arsenate suspensions. Likewise, in accordance with the hypothesis is the fact that a relatively great concentration failed to cause a short survival time, for the shortest time obtained was 229 minutes (harmonic mean).

In calculating survival times for experiment 8 according to equations 14 or 19, it was found that the data yielded no clear-cut value for the constant $a$, and no value for $c_d$. With no value for $c_d$, it was not possible to determine $n$ and $K$ from values lying below $c_d$, as was done for the sodium arsenate curves of this and the sodium metarsenite curves of the previous paper. In accordance with the above discussion, however, it may be assumed that the lead arsenate would be only slightly in solution at very high total concentrations and the percentage of the total concentration dissociated would be so slight that the constant $p$ could be assigned either the value zero or a value very near to zero. Furthermore, in accordance with the above results and discussion, inasmuch as the arsenate ion from sodium arsenate has the same toxicity as the arsenite ion from sodium arsenite, it may be assumed that the arsenate ion from lead arsenate would have the same or nearly the same toxicity. On these assumptions the values of the constants $a$, $n$, and $K$, previously determined, and a value of $c_o$ close to those previously determined in fitting the sodium arsenate and metarsenite curves were utilized, and values of $c_d$ and $m$ were thus obtained by successive approximation. The final values of these constants are shown in table 5.

The toxicity of the lead ion has not been included in the above considerations because the authors have data, reserved for a later publication, which indicate that, when certain salts capable of forming toxic cations and toxic anions by means of dissociation are injected into roaches, the cations and anions may exert their toxic action with considerable independence of each other. The data also indicate that the survival time of an insect may be determined by the more toxic of the two ions. As there is reason to believe that the arsenate ion is more toxic than the lead ion in this experiment, only the arsenate ion was considered in the calculation of the survival times of the mealworm larvae (Table 3).

As the colloidal lead arsenate curve is uncomplicated by a visible region of inflection, it is possible to fit it by means of a simplification of equations 14 and 19. As pointed out above, the constant $p$ can be equated to zero. Since the observed curve contains no inflection, the lowest injected concentration is greater than $c_d$ and $(c_d/c_{d/c})^m$ does not attain the value 1 at or above the lowest concentration used. By setting $c_o$ equal to zero, equation 14 is transformed into equation 19. When $p$ is set equal to zero in equation 19, the latter reduces to

$$t_s-a=\frac{K}{n-1}\left\{\frac{1}{\left[c\left(\frac{c_d}{c}\right)^m\right]^{n-1}}\right\} \qquad (23)$$

or

$$t_s-a=hc^{-q}, \qquad (24)$$

where

$$h=\frac{K}{(n-1)c_d^{m(n-1)}} \text{ and } q=(1-m)(n-1).$$

In calculating survival times by equation 24, $h$ and $q$ can be evaluated as fol-

lows: The constant $c_o$ in equation 14 is equated to zero, and the values of the other constants are adjusted slightly to get a good fit by equation 19, into which 14 was transformed by the elimination of $c_o$. Then setting $p$ equal to zero in equation 19 and slightly adjusting the values of the remaining constants to compensate for the absence of $p$, a good fit is obtained by equation 23, into which 19 was transformed by the elimination of $p$. The values of $h$ and $q$ are readily obtained by use of the above equations relating them to the other constants. In this way it was found that, when $h=248.85$ and $q=1$, the survival times shown in table 3 could be calculated. Although the values of the constants in equations 14 and 19 for experiments 1, 6, and 7 have been used in getting the final values of the constants in equation 24, the fact that the more complex equation 14 logically reduces to the simple equation 24, which is comparable to the well-known form $ct=$constant, is of interest.

This analysis, together with published (Yeager & Munson 1945) and unpublished work, have led the authors to the following concepts:

(1) The familiar, simple expression $ct=$constant, or a simple, well-known variety of this equation, may be found applicable as a mathematical expression of a biophysical system in special cases, where simplification within limits of experimental error can be achieved through the reduction of certain factors to zero, or where mutually antagonistic factors are so equally opposed that they can be neglected.

(2) When simplification has been achieved in this manner, the resulting expression $ct=$constant, or one of its simple, well-known varieties, represents only an approximate description of the biophysical system.

(3) The apparent linear relationship between the logarithmic forms of $c$ and $t$ in the logarithmic forms of such simplified expressions is likely to have either only an approximate or, through a balance of mutually opposing factors, a more or less fortuitous relationship to the biophysical system.

(4) An uncritical use of such simplified expressions may tend to obscure rather than elucidate fundamental relationships in the biophysical system.

Survival times calculated by equation 19 for mealworm larvae (Exp. 9) are shown in table 4, and some are plotted in figure 1. The agreement between the calculated and observed times is good, considering the semiquantitative injection method used. The values of the constants used to obtain the fits are given in table 5. The data in table 4, the values of $K$ (Table 5), and figure 1 suggest that sodium metarsenite is less toxic to the *Tenebrio* larvae than to the roaches.

As pointed out in the previous paper, plotting $c$ vs. $100[p+(1-p)(c_d/c)^m]$ yields curves that may be interpreted as representing percentage dissociation of the poison in the body fluid of the injected insect. Such dissociation curves for experiments 1, 6, 7, and 9 are shown in figure 2, which may be compared with figure 5 of the previous paper. As in that paper, in this one the blood volume of cockroach nymphs is taken to be 0.1 ml. per gram of body weight. Analogous values for colloidal lead arsenate (Expt. 8) are given in the last column of table 4.

If other factors are neglected and only the dilution of the injected poison by the blood is considered, the blood volume of the mealworm can be estimated from the ratio of the $c_d$ values from experiments 9 and 1 (Table 5) when the blood volume of the roach is taken as 0.1 ml. per gram of body weight. Such a calculation indicates the blood volume of the mealworm to be approximately 0.22 ml. per gram of body weight. This value for *Tenebrio* was used to convert injected concentration to a blood-concentration basis. The procedure just described is suggested as a new method for the estimation of blood volume in an insect.

In accordance with observations made in connection with the previous work, it was found in these experiments that, after the injection of one of the arsenical poisons, the lethally affected insects passed through successive symptomatic stages with little or no tendency to recover. This symptomatic behavior is illustrated graphically in figure 3, where the symbols for the symptomatic stages have been given values and plotted against a 100-unit time scale on which, for a given concentration, a unit is equal to the survival time for that concentration divided by 100. Conversely, to get an observed survival time from the arbitrary time

scale in figure 3, the appropriate value of the scale is multiplied by an appropriate unit value. The values assigned to the letters representing symptomatic stages were selected in such a way that, when they are plotted against the time scale, the plotted points fall along a straight line. Thus a straight line representing arsenical poisoning, which may serve as a standard, was obtained by using the numerical values given in the legend to figure 3. This procedure is recommended as a graphical method of comparing the symptomatic behavior of insects to different poisons against a common (though somewhat arbitrary) scale.

By use of this method it is shown that the poisoned insects develop the same continuously progressive symptoms, regardless of whether they received low, intermediate, or high dosages of these arsenical poisons (Fig. 3). This continuous worsening of the sickened insects appears to be characteristic for these poisons. Thus, an insect injected with any lethal concentration of any one of the poisons used in this work showed symptomatic behavior represented somewhere within the area between the two broken lines of figure 3; that is, a curve representing its progress from the normal condition through successive symptoms to death falls between the two broken lines; on the average, and ideally, it would be represented by the straight line. On the contrary, the curve for controls follows along the horizontal axis at the *A* level until it reaches about 90 on the arbitrary scale and then, between about 90 and 100, it suddenly passes very rapidly upward to the death point. Insects receiving sublethal dosages of the arsenicals tend according to our observations to behave like the controls.

SUMMARY AND CONCLUSIONS.—When injected into American roaches, sodium monohydrogen orthoarsenate, like sodium metarsenite, yielded hyperbolic concentration-survival time curves characterized by a region of inflection and by a critical zone. Lead arsenate yielded a curve that exhibited no inflection but did have a critical zone. Sodium arsenate and sodium metarsenite were equally toxic to roaches, except in the higher molar concentrations, where the arsenite was the more toxic. The lead arsenate was less toxic than either. These results are given a rational explanation on the basis of a dissociation hypothesis discussed fully in a previous paper. According to that hypothesis, in these experiments the arsenical ions formed by the sodium metarsenite and the sodium arsenate (and probably by the lead arsenate) are equally toxic and the differences in toxicity between these salts are due largely, if not entirely, to differences in the degree of dissociation of the salts. Survival times that agree well with the observed times were calculated by use of equations based on the dissociation hypothesis. Curves considered to represent the percentage dissociation of the poison in the blood of the insect were obtained by plotting values of $100]p+(1-p)(c_d/c)^m]$ against concentration $c$. Methods are suggested for estimating the blood volume of an insect and for comparing toxicity symptoms caused by different poisons. Suggestions are made as to why such simple expressions as $ct$=constant may happen to apply to biophysical systems under certain conditions of simplification. Evidence is presented that the mealworm *Tenebrio molitor* is more resistant than the American cockroach, *Periplaneta americana*, to poisoning by sodium metarsenite applied as in these experiments.—11-23-45.

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# Ethylene Dibromide and Dichloropropane-Dichloropropene Mixture for Wireworm Control

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The inhibiting factor in the use of soil fumigants in the past for wireworm control on a large scale has been the combined high cost of fumigant and application. The recent appearance of D-D mixture (1,2-dichloropropane 1,3-dichloropropene) and ethylene dibromide, however, together with the development of new equipment for application of these chemicals makes it appear possible that for the first time wireworms can be controlled economically on a large scale.

Field tests using D-D mixture have been underway since 1943 in California, and tests with ethylene dibromide since December 1944. The tests reported herein are those in which both fumigants were compared directly. The species involved was chiefly the sugar beet wireworm, *Limonius californicus* (Mann.)

Materials Used.—D-D mixture[1] is a combination of saturated and unsaturated chlorinated compounds, chiefly 1,2-dichloropropane and 1,3-dichloropropene which was first used by Carter (1943) and reported on later more fully by Carter (1945). Stone (1944) reported it in California for wireworm control when used in emulsion form. In the present experiments the D-D mixture was used undiluted as supplied. Ethylene dibromide was supplied as a 10 or 15 per cent (by volume) solution in a naphtha 200 base and was used at the rate of from 2 to 7.5 gallons of pure ethylene dibromide per acre.

Method of Application.—The chemicals were applied by means of two commercial trailer applicators having a series of soil drills spaced at from 12 to 15 inches and drilled as a continuous stream at a depth of from 6 to 8 inches. The fumigants were forced into the ground under low pressures, and dosage calculated from an adjustment of speed of the tractor, size of orifice (in the case of one applicator) and pressure at which the fumigant was applied. The soil in all cases was in good friable condition, and a drag or roller was used to seal the surface of the ground in most instances.

Results of Tests.—On December 10, 1944 ethylene dibromide was applied to a field at Salinas in replicated one eight acre plots the rest of which was being treated commercially with 400 pounds of D-D mixture and 35 pounds of anhydrous ammonia per acre. The temperature on this date was 50° F. at an 8 inch depth and the fumigant was applied with the Shell commercial applicator as a continuous stream at a depth of 8 inches with 15 inch spacings. The soil type was Salinas silty clay loam, and the field was in good condition for planting. Lettuce was planted 10 days following treatment and the December rains were used to germinate the seed. The results of this test indicated that the combination of either fumigant especially with the simultaneous application of anhydrous ammonia gave substantial increases in yields of lettuce on wireworm infested soil. The results are summarized in table 1.

During 1945 tests were conducted in the Northern Sacramento Valley at Gridley and Meridian to test the relative efficacy of different dosages of D-D mixture and ethylene dibromide. D-D mixture was tested at 20, 40 and 60 gallons per acre, ethylene dibromide at 30 and 40 gallons of 10 per cent (by volume) per acre, and compared with untreated checks. Three replications arranged as randomized blocks, 25 feet wide by 200 feet deep were used. The ethylene dibromide was applied with the *Dow* commercial applicator and the D-D mixture by the *Shell* experimental applicator. Both machines applied a continuous stream of fumigant to a depth of from 6 to 8 inches.

At Gridley the fumigants were applied May 1, 1945. The temperature at the 6 inch level was 87° F. and at the 12 inch level, 73° F. and the moisture content 9.1 per cent. The soil was Columbia fine sandy loam. Baby lima beans were planted two weeks following the treatment. On June 20 stand counts indicated no significant difference between the different treat-

[1] The D-D mixture and ammonia was supplied by the Shell Chemical Company of San Francisco, California; the ethylene dibromide by the Dow Chemical Company of Midland, Michigan.

Table 1.—Summary of the effect of application of ethylene dibromide and D-D mixture to a field at Salinas infested with the sugar beet wireworm, applied on December 10, 1944.

| Treatment per Acre | Per Cent of Damaged Lettuce Plants on April 5, 1945 | Calculated Number of 80 Pound Trimmed Crates of Lettuce Per Acre |
|---|---|---|
| D-D Mixture, 40 gallons, plus 35 pounds anhydrous ammonia | 0.14 | 249 |
| Ethylene dibromide, 42 gallons (15% by vol.), plus 30 pounds anhydrous ammonia | 0.12 | 298 |
| Ethylene dibromide, 42 gallons (15%) | 0.36 | 189 |
| Ethylene dibromide, 50 gallons (15%) | 0.40 | 214 |
| Untreated | 5.57 | 173 |

ments, but soil siftings indicated that both ethylene dibromide treatments gave complete reduction of wireworms to the depth and in the samples examined. The higher dosages of D-D mixture, 40 and 60 gallons per acre, also gave almost complete kill of wireworms. It was observed that siftings to a depth of 10 inches do not always give a complete picture of kill as a few wireworms at greater depths in the soil are not killed. The results of this experiment are shown in table 2.

two weeks. The results of these tests indicated that on June 7, on the basis of stand counts that the ethylene dibromide treatments gave a protection from wireworm comparable to the 60 gallon per acre treatment of D-D. The results are summarized in table 3.

On June 4, 1945 at Salinas another trial was conducted testing 40 gallons of D-D mixture, 40 gallons of 5 per cent ethylene dibromide and untreated checks in a field heavily infested with sugar beet

Table 2.—Results of tests comparing different dosages of D-D mixture and ethylene dibromide for wireworm control at Gridley, applied May 1, 1945.

| Treatment Per Acre | Number of Lima Bean Plants Per Foot of row | Per Cent Reduction in Number of Wireworms[1] |
|---|---|---|
| D-D mixture, 20 gallons | 1.89 | 75 |
| D-D mixture, 40 gallons | 1.90 | 92 |
| D-D mixture, 60 gallons | 1.81 | 100 |
| Check | 0.87 | — |
| Ethylene dibromide 30 gallons (10% by vol.) | 2.13 | 100 |
| Ethylene dibromide 40 gallons (10% by vol.) | 1.81 | 100 |

[1] Based on total number of wireworms in 8 one square foot samples of soil to a depth of 10 inches for each treatment.

At Meridian a similar test was conducted on May 2. The soil was Columbia silty clay loam and the temperature at the 6 inch level was 70° F., at 12 inches, 68° F., and the moisture content 14 per cent. Baby lima beans were planted in

wireworms. The plots were 30 feet wide by 500 feet long, using 3 replications for each treatment with check strips of similar width between treatments. The materials were applied with the *Shell* commercial applicator using 15 inch spacings

Table 3.—Results of treatment of a field at Meridian with ethylene dibromide and D-D mixture on subsequent damage to lima bean plants—counts taken June 7, 1945.

| Treatment Per Acre | Number of Lima Bean Plants Damaged by Wireworms on 1/24 Acre | Per Cent of Lima Bean Plants Damaged by Wireworms |
|---|---|---|
| D-D mixture, 20 gallons | 70 | 2.8 |
| D-D mixture, 40 gallons | 78 | 3.2 |
| D-D mixture, 60 gallons | 33 | 1.3 |
| Check | 229 | 11.9 |
| Ethylene dibromide 30 gallons (10% by vol.) | 30 | 1.3 |
| Ethylene dibromide 40 gallons (10% by vol.) | 11 | 0.5 |

at a depth of 8 inches. On September 20, 1945 when yields were checked, the 40 gallons of D-D mixture yielded 408.3 eighty pound crates of trimmed lettuce, the ethylene dibromide, 289.1 crates, and the untreated checks 58.2 crates per acre.

DISCUSSION.—From the results obtained it seems that both D-D mixture and ethylene dibromide offer good possibilities for the economical control of wireworms in land under irrigation and intensive cultivation in California. In tests reported herein and others over a period of two years using D-D mixture, the 40 gallon (400 pounds) treatment per acre offers the most economical control and greatest returns per acre although not effecting a complete kill of wireworms. The simultaneous application of 35 pounds of ammonia with the fumigant, particularly in late fall treatments give the greatest yields when followed by lettuce. It is probable that the reduction in numbers of wireworms together with the presence of ammoniacal nitrogen in the spring accounts for the more rapid growth, greener color and greater yields where the combination fumigant-fertilizer is used. The recent work by Tam (1945) might indicate that the 40 gallon per acre treatment by D-D mixture suppresses nitrification for a limited period and in this interim the lettuce plant is able to utilize ammoniacal nitrogen supplied at the time of application of the fumigant. This additional nitrogen supplied was not used as a substitute for the regular fertilizer program using balanced commercial fertilizers, or manure.

It would seem from these tests that ethylene dibromide can be used at lower dosages to obtain wireworm control than can D-D mixture. The resultant crop yields, however, can only be ascertained by future tests using all types of crops. For example, beans following ethylene dibromide often give better growth, than can be explained on a basis of the control of wireworms alone. On the other hand if beans are planted too soon following the higher dosages of D-D mixture, damage will result. The fumigant used in particular instances may have to be chosen on a basis of the crop to be treated.

SUMMARY.—Tests comparing different dosages of D-D mixture and ethylene dibromide were conducted at Salinas, Meridian and Gridley, California during 1944–45 indicated that these fumigants offer good possibilities for the economical control of wireworms when applied in continuous streams at a depth of from 6 to 8 inches and 12 to 15 inch spacings. With D-D mixture a dosage of 40 gallons (400 pounds) per acre gives a satisfactory reduction in wireworm control and subsequent increased yields of lettuce and beans.

The simultaneous application of 35 pounds of anhydrous ammonia with 40 gallons of D-D mixture in the fall, gave the greatest increases in yields of lettuce the following spring.

Ethylene dibromide at both 30 and 40 gallons of 10 per cent strength (by volume) in a naphtha-200 thinner per acre, was found to give good kills of wireworms, increased stands and yields. This dosage compared in most cases with 40 to 60 gallons of D-D mixture from the stand point of actual kill of wireworms, although the increased yields following treatment may depend upon what crop is to be planted and other factors such as the interval of time between fumigation and date of planting.—10-22-45.

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# Mortality of the Mexican Fruitfly in Mangoes Treated by the Vapor-Heat Process

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The vapor-heat method of fruit sterilization was developed in Florida in 1929 during the campaign against the Mediterranean fruitfly, *Ceratitis capitata* (Wied.). It has been discussed by Baker *et al.* (1944). As a result of studies that determined its lethal action on larvae of the Mexican fruitfly, *Anastrepha ludens* (Loew),[1] the process was authorized in 1938 for the treatment of citrus fruit in the Rio Grande Valley in Texas.

The continuation of the studies on the vapor-heat sterilization of mangoes infested with *Anastrepha ludens* has afforded the opportunity to determine the mortality curve as a basis for treatment of that fruit by methods set forth by Baker (1939). Twenty-three experiments were made with mangoes in 1943, 10 of them with off-season fruit, from February 13 to March 13, and 13 during the normal fruiting season, from May 3 to August 12. The fruit was obtained at first from Cuernavaca and later, when the Cuernavacan fruit had disappeared, from Tepoztlan, Morelos.

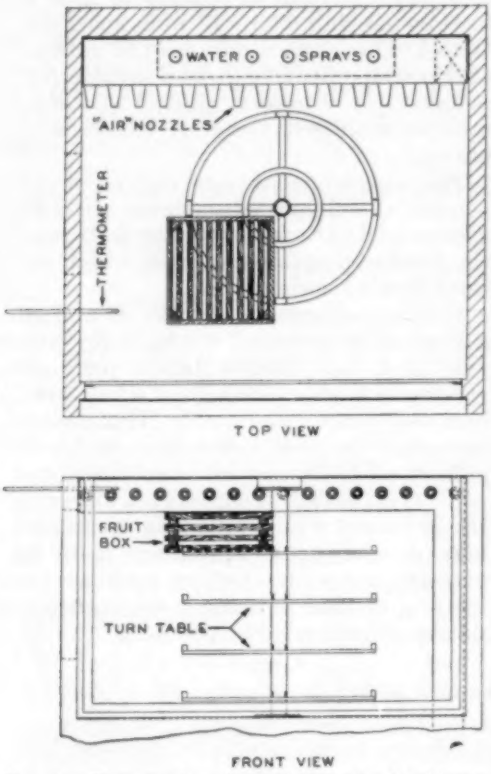


FIG. 1.—Cross-section views of vapor-heat cabinet: *A*, Top; *B*, front.

The vapor-heat process of fruit sterilization utilizes air, saturated water vapor, and water in the form of a fine mist circulated in large volume throughout the load, and is dependent for its success on the latent heat of evaporation released by condensation. These conditions may be obtained in two ways. In the first procedure the heat is supplied by electric heating elements. A current of air is blown or drawn across these elements, and into this current a fine water spray is injected. The mixture of air, vapor, and water mist is then forced through the load. In the second procedure live low-pressure steam is injected into a stream of air to which a water spray is added if necessary, and the resulting air, vapor, and water mist is drawn through a series of baffles, to eliminate large water particles, and is then forced through the load.

The studies discussed herein were made in a conditioning cabinet known as "Government size," the inside dimensions being 47 by 46 by 30 inches. It was operated according to the first procedure described in the preceding paragraph. Two views of the interior of the cabinet, with a turntable designed and constructed by Juan A. Ramirez to permit the removal of any lot of fruit at any time during sterilization, are shown in figure 1. In commercial treatments in the lower Rio Grande Valley of Texas the second procedure is employed.

In a complete experiment 20 boxes of approximately 60 fruits each were used, the fruit in 4 boxes serving as a control and that in the other 16 receiving the treatment. Surviving fruitflies were noted by holding the fruit in trays over clean sand, as described by Mason & McBride (1934). To reduce error due to variable

[1] The studies were conducted on both mangoes and citrus fruits by personnel now in the Division of Fruitfly Investigations of the Bureau of Entomology and Plant Quarantine.

factors, such as the condition of the fruit, the degree of infestation, the larval stages in the fruit, and the resistance of the larvae, each experiment was designed so that 8 boxes of fruit received one exposure and 8 boxes another exposure. A diagrammatic representation of the box set-up inside the sterilizing cabinet is presented in figure 2. For removals the 16 boxes were divided into two series, the positions being equalized as much as possible. Series 1 consisted of boxes numbered 1, 3, 6, 8, 9, 11, 14, and 16. The remaining boxes fell in series 2. The order of removal of the two series alternated with each experiment; that is, the boxes in series 1 were removed first in one experiment, and those in series 2 first in the following experiment, and so on. In two experiments all 16 boxes were removed after 11 hours of treatment, because the turntable stuck.

The time periods in the experiments ranged from 8 to 13 hours, including the standard 8-hour approach period, during which the temperature of the fruit was raised gradually from room temperature to 43.3° C. (110° F.) by means of control with a variable-temperature apparatus (Stone 1939).

Temperatures at the approximate center of the fruit in each of the 16 boxes were determined hourly by means of resistance thermometers equipped with metal bulbs and having copper-wound and rubber-insulated leads. Readings were made on a portable testing set, which was accurate to within 0.05 ohm when checked with a 100-ohm Bureau of Standards resistance standard. The leads were calibrated in both air and water against a Bureau of Standards thermometer graduated in 0.1° C., and the average maximum deviation was approximately 0.31°. This is the error due to reading plus the error inherent in the leads. The average maximum deviation of the same leads in the fruit during the portion of the studies conducted at 43.3° was approximately 0.51°. This additional error of 0.20° (0.51° −0.31°) may be attributed to differences in the 16 positions in the vapor-heat sterilizing cabinet.

The temperature of the air mixture was recorded each hour with a Bureau of Standards mercury thermometer and with a resistance thermometer. The temperatures recorded in the fruit approximated these air-mixture temperatures. After a natural lag during the first 8 hours of treatment while the temperature was gradually being raised to 43.3° C., the temperatures of the fruit and of the air mixture were in equilibrium to ±0.1°

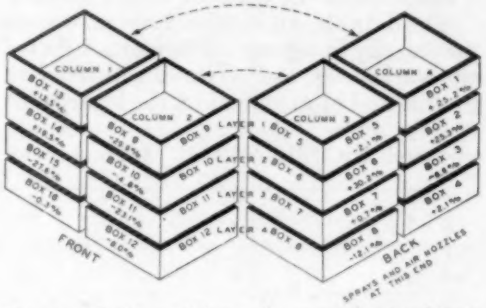


FIG. 2.—Position of boxes in vapor-heat cabinet.

during the remainder of the experiment. Table 1 gives the air-mixture temperatures in the sterilizing cabinet during the 23 experiments conducted.

**Table 1.—Temperatures of the air mixture during vapor-heat treatment of mangoes infested with *Anastrepha ludens*.**

| Exposure Period | Prescribed Temperature[1] | Maximum Deviations[2] | |
|---|---|---|---|
| | | Positive | Negative |
| *Hours* | °C. | °C. | °C. |
| 1 | 28.3 | 0.3 | 4.3 |
| 2 | 33.6 | .3 | 5.9 |
| 3 | 37.4 | .5 | .8 |
| 4 | 40.1 | .2 | .6 |
| 5 | 41.7 | .3[3] | 1.1 |
| 6 | 42.7 | .3 | .7 |
| 7 | 43.2 | .0 | .9 |
| 8 | 43.3 | .2[4] | .2 |
| 9 | 43.3 | .2[5] | .2 |
| 10 | 43.3 | .2 | .2 |
| 11 | 43.3 | .2 | .2 |
| 12 | 43.3 | .1 | .1 |
| 13 | 43.3 | .2 | .1 |

[1] Average temperatures observed in commercial sterilization of citrus, as recorded by personnel of the Division of fruitfly Control, Bureau of Entomology and Plant Quarantine.
[2] Based on the readings of a Bureau of Standards thermometer graduated in tenths, suspended in the vapor mixture.
[3] In one experiment 1.1° for a short period.
[4] In one experiment 0.4°.
[5] In one experiment 0.6°.

It may be seen in table 1 that the large negative deviations from prescribed temperatures occurred especially during the early hours of treatment. This lag was the result of low fruit temperatures at the start of some of the experiments. Fruit was stored in the attic prior to treatment, and fruit temperatures as low as 11° C. immediately preceding treatment were recorded. It will be noted, however, that

positive deviations were much more closely controlled than negative deviations. This guarantees a more severe test where recommendations involving freedom from infestation are concerned. Table 2 summarizes the data for each exposure.

The data shown in table 2 are presented graphically in figure 3. The mortalities for the various exposures were converted to probits and plotted against the logarithms of exposure, following the procedure adopted by Bliss (1935). It has been shown[2] that the logarithmic conversion of the units of time is not strictly applicable in the present studies unless a constant is included. This constant is dependent upon the mortality during the first 8 hours and has been called the approach-period equivalent. A value of 4 hours was used in this case. In plotting the data the first 8 hours of treatment, which actually involved a variable temperature, ranging from about 20° to 43.3° C. were considered equivalent to 4 hours of exposure at 43.3°.

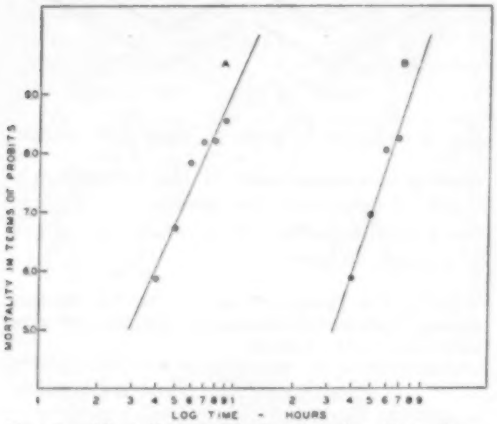


FIG. 3.—Mortality curves showing the effect of vapor-heat treatment on eggs and larvae of the Mexican fruitfly. Line *A* is based on the number of larvae surviving and developing to the pupal stage, line *B* on the number of survivors that developed into adults.

The regression lines were calculated according to the procedure outlined by Bliss (1935), except that his weighting coefficients were not strictly applicable in this case. The error-of-population estimate is included in all these data, which shifts the points with the heaviest weights above 50 per cent mortality. Because of the lack of appropriate weighting coefficients, weights of 1 were used in all cases. The regression line based on puparia counts calls for 5.7 hours of exposure at 43.3° C., in addition to the 8-hour approach period, to obtain security at probit 9 (mortality of 99.9968 per cent). This is in good agreement with the recommendation of 6 hours adopted for citrus in the Rio Grande Valley of Texas under the Mexican fruitfly quarantine (United

[2] Unpublished report by Starr.

**Table 2.—Mortality of *Anastrepha ludens* larvae in mangoes treated by vapor-heat sterilization at a temperature of 43.3° C.[1]**

| Exposure[2] | Fruits | Estimated Eggs and Larvae[3] | Survivors | | Emergence | Mortality Based on Puparia | Probit |
|---|---|---|---|---|---|---|---|
| | | | Puparia | Adults | | | |
| *Hours* | *Number* | *Number* | *Number* | *Number* | *Per Cent* | *Per Cent* | |
| 0 | 2,664 | 23,672 | 4557 | 3121 | 68.49 | 80.75 | 5.868 |
| Control | 666 | 5,918 | 5918 | 4,134 | 69.85 | — | |
| 1 | 3,640 | 36,124 | 1572 | 728 | 46.31 | 95.65 | 6.711 |
| Control | 910 | 9,031 | 9031 | 7180 | 79.50 | — | |
| 2 | 3,264 | 32,088 | 78 | 27 | 34.62 | 99.757 | 7.816 |
| Control | 816 | 8,022 | 8022 | 5784 | 72.10 | — | |
| 3 | 4,680 | 31,832 | 23 | 5 | 21.74 | 99.928 | 8.187 |
| Control | 1,170 | 7,958 | 7958 | 2116 | 26.59 | — | |
| 4 | 4,296 | 25,944 | 18 | 0 | 0 | 99.931 | 8.199 |
| Control | 1,074 | 6,486 | 6486 | 691 | 10.65 | — | |
| 5 | 1,696 | 14,614 | 3 | 0 | 0 | 99.979 | 8.529 |
| Control | 424 | 3,654 | 3654 | 221 | 6.05 | — | |
| Total | 25,300 | 205,343 | — | — | — | — | — |

[1] Temperature at approximate center of fruit.
[2] Does not include the 8-hour approach period.
[3] Based on the number of puparia recovered from control fruits.

**Table 3.—Distribution of *Anastrepha ludens* larvae surviving exposures in 16 positions in the vapor-heat cabinet.**

| Position | Survivors in Experiment | | | | | | | | | | Total Survivors |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1[1,4] | 2[2] | 2[3] | 4[2] | 5[4] | 6[2] | 7[4] | 8[2] | 9[2] | 10[2] | |
| *Series 1* | | | | | | | | | | | |
| 1 | 0 | 32 | 80 | 150 | 1 | 32 | 6 | 27 | 25 | 70 | 423 |
| 3 | 0 | 11 | 98 | 95 | 0 | 35 | 1 | 7 | 9 | 53 | 309 |
| 6 | 0 | 11 | 50 | 202 | 0 | 66 | 1 | 8 | 8 | 94 | 440 |
| 8 | 0 | 16 | 38 | 146 | 0 | 36 | 0 | 1 | 13 | 47 | 297 |
| 9 | 0 | 17 | 39 | 68 | 0 | 15 | 0 | 0 | 10 | 88 | 237 |
| 11 | 0 | 4 | 29 | 100 | 0 | 27 | 0 | 0 | 0 | 100 | 260 |
| 14 | 0 | 14 | 48 | 147 | 3 | 41 | 1 | 8 | 4 | 138 | 404 |
| 16 | 0 | 5 | 50 | 120 | 0 | 37 | 1 | 16 | 9 | 99 | 337 |
| Total | 0 | 110 | 432 | 1028 | 4 | 289 | 10 | 67 | 78 | 689 | 2,707 |
| | 1[2] | 2[4] | 3[2] | 4[3] | 5[3] | 6[4] | 7[2] | 8[2] | 9[1,4] | 10[4] | |
| *Series 2* | | | | | | | | | | | |
| 2 | 134 | 0 | 218 | 42 | 17 | 19 | 40 | 79 | 0 | 0 | 549 |
| 4 | 118 | 0 | 126 | 65 | 17 | 1 | 21 | 99 | 0 | 0 | 447 |
| 5 | 61 | 0 | 179 | 72 | 43 | 24 | 19 | 27 | 0 | 4 | 429 |
| 7 | 75 | 0 | 242 | 39 | 11 | 1 | 12 | 61 | 0 | 0 | 441 |
| 10 | 181 | 1 | 148 | 25 | 2 | 4 | 14 | 42 | 0 | 0 | 417 |
| 12 | 120 | 0 | 214 | 15 | 3 | 1 | 10 | 40 | 0 | 0 | 403 |
| 13 | 135 | 0 | 210 | 38 | 17 | 7 | 26 | 64 | 0 | 0 | 497 |
| 15 | 70 | 0 | 158 | 31 | 3 | 2 | 14 | 39 | 0 | 0 | 317 |
| Total | 894 | 1 | 1495 | 327 | 113 | 59 | 156 | 451 | 0 | 4 | 3,500 |
| *Control* (box no.): | | | | | | | | | | | |
| 1 | 990 | 747 | 913 | 588 | 549 | 669 | 432 | 448 | 304 | 324 | |
| 2 | 985 | 758 | 790 | 413 | 625 | 712 | 416 | 457 | 274 | 266 | |
| 3 | 871 | 586 | 894 | 431 | 819 | 578 | 533 | 432 | 286 | 239 | |
| 4 | 1069 | 673 | 632 | 480 | 722 | 678 | 525 | 449 | 249 | 165 | |
| Total | 3915 | 2764 | 3229 | 1912 | 2715 | 2637 | 1906 | 1786 | 1113 | 994 | 22,971 |

[1] Omitted from analyses because there were no survivors.
[2] 8-hour treatment.
[3] 9-hour treatment.
[4] 10-hour treatment.

States Bureau of Entomology and Plant Quarantine 1938) as a result of similar studies by Stone[2] in 1933 with *Anastrepha ludens* in mangoes and oranges. The line based on adult counts, corrected for natural mortality in the controls, gives a probit of 9 with a treatment of 3.9 hours beyond the approach period. The difference between 5.7 and 3.9 hours indicates the added security in the use of puparia in constructing mortality curves.

In experiments with the vapor-heat process all survivors in a given experiment were, in some instances, recorded from a single box of fruit. This suggested the possibility that variation in mortality might be due to position in the sterilizing cabinet. The significance of the position error alone was tested by several analyses of variance. To determine whether this condition existed, the first 10 experiments were designed for the specific purpose of detecting error due to position. In order that the data might also be used in estab-

**Table 4.—Analysis of variance of controls in vapor-heat experiments with mangoes infested by *Anastrepha ludens*.**

| Source of Variation | Degrees of Freedom | Sum of Squares | Estimate of Variance |
|---|---|---|---|
| Total | 39 | 2,098,639.97 | — |
| Experiments | 9 | 1,914,213.23 | 212,690.36 |
| Randomization | 30 | 184,426.74 | 6,137.56 |

Standard deviation = $\sqrt{6137.56} = 78.34$.

lishing a regression line, removals were made in two series in each experiment. To some extent this was unfortunate, because no way was found to combine both series in analyzing the data.

Table 3 lists survivals of Mexican fruitfly larvae for each position in the vapor-heat cabinet after treatments of 8 to 10 hours, including the approach period.

The fruitfly populations in control lots of fruit were analyzed to determine the randomization error in experiments 1–10; each experiment had 4 control boxes averaging about 60 fruits per box. The analysis of the data for the controls is given in table 4.

The combined error due to position was studied by comparing the survival in each box with the mean for each series (Table 3). For example, in series 1, with 2707 total survivors, box 1 contributed 423 survivors, which represented a positive deviation of 25.1 per cent from the mean of 338. The percentage difference for each position is shown diagrammatically in figure 2. The standard error for position was calculated from these 16 deviations as follows:

$$Sx^2 = (13.5)^2 + (19.5)^2 \ldots + (2.1)^2$$
$$= 5{,}255.86$$
$$S_x = \sqrt{\frac{5{,}255.86}{15}} = 18.7 \text{ per cent}$$

This apparent position error includes the error of randomization and an additional error, which may be termed "the error of susceptibility." The error of susceptibility may be explained by separating it from the other two errors in the following example: If we assume that exactly 500 eggs and larvae were included in each box and that the 16 boxes were treated to produce 95 per cent mortality in a perfect cabinet, the variation in the resistance of the insects to the treatment would prevent the exact expected number of 25 survivors from appearing in each box. The variation in the number of survivors from the expected number would be the error of susceptibility.

**Table 5.—The effect of the variances in combinations of positions of boxes of fruit treated with vapor heat for control of *Anastrepha ludens*.**

| Combination of Positions[1] | Series | Position | Variance Ratios, F | |
|---|---|---|---|---|
| | | | Found | Required for 5% Level |
| Individual | 1 | 1, 3, 6, 8, 9, 11, 14, 16 | 1.77 | 2.18 |
| | 2 | 2, 4, 5, 7, 10, 12, 13, 15 | 1.00 | 2.18 |
| Cubes | 1 | 1+6, 3+8, 9+14, 11+16 | 2.35 | 2.76 |
| | 2 | 2+5, 4+7, 10+13, 12+15 | 1.34 | 2.76 |
| Columns | 1 | 1+3, 6+8, 9+11, 14+16 | 2.12 | 2.76 |
| | 2 | 2+4, 5+7, 10+12, 13+15 | .77 | 2.76 |
| Sides | 1 | Front, 9, 11, 14, 16<br>Back, 1, 3, 6, 8 | 1.90 | 4.00 |
| | 2 | Front, 10, 12, 13, 15<br>Back, 2, 4, 5, 7 | 1.48 | 4.00 |
| Layers | 1 | 1+9, 6+14, 3+11, 8+16 | 2.05 | 2.76 |
| | 2 | 5+13, 2+10, 7+15, 4+12 | .91 | 2.76 |

[1] In all combinations of positions experiment 1 was omitted in series 1 and experiment 9 in series 2, because there were no survivors.

An examination of the data indicated more survivors for boxes 1, 2, 5, and 6, than for any similar combination of four boxes. This group comprised the upper four boxes at the back of the cabinet, where the mixture from the water sprays and the air nozzles originated. The boxes were therefore combined as cubes for each series, and analyses of variance were applied to the data. Similar analyses were also spplied to the individual positions and to other combinations of positions, such as columns, sides, and layers. A complete summary of analytical results is given in table 5.

As can be seen from the foregoing analyses of variance, there was no significant difference in the survival due to position, individually or combined into columns, sides, cubes, or layers. Any error due to position was small and had little influence on the results. As was to be expected, the difference between experiments was highly significant, because it included the treatment time, which ranged from 8 to 10

hours. Should further work be found necessary to determine position error more exactly, it probably would be better to remove all 16 boxes at one time, thereby making it possible to compare all the positions directly with one another. Removals might best be made after 9 hours of exposure, which gave a mortality of 95.65 per cent, with only 3 boxes out of 64 recording no survivors.

SUMMARY.—The vapor-heat process of fruit sterilization has been applied in a study of the mortality of the Mexican fruitfly, *Anastrepha ludens* (Loew), in relation to the treatment of mangoes infested by that species. The experiments were conducted in a conditioning cabinet equipped with a turntable of 16-tray capacity, designed to permit removal of random lots of fruit during treatment. The data submitted cover 23 experiments using 25,300 mangoes with an estimated population of 205,343 larvae. Treatment periods were from 8 to 13 hours, the first 8 hours of which represented the approach period needed to reach temperature equilibrium at 43.3° C. (110° F.). Regression lines calculated from these data by using the method of probits gave an exposure security at probit 9 (mortality of 99.9968 per cent) of 5.7 hours based on the number of survivors attaining the pupal stage, and 3.9 hours based on the number attaining the adult stage. These periods are in addition to the 8 hours used in the approach. The experiments were designed so that errors due to differences in position in the vapor-heat cabinet might be studied. The data were subjected to analyses of variance. The error due to position was found not to be significant.—6-10-45.

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# Incomplete Block Experimental Designs in Insect Population Problems

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Incomplete block designs are special applications of the principle of confounding which have been developed in recent years to meet certain definite needs in field-plot experimentation. With a large number of experimental treatments such designs as ordinary randomized blocks may lose much of their efficiency in error control because of increase of block size. In this situation smaller blocks with incomplete sets of treatments in each may be used. Differences between the small blocks are evaluated and allowed for in analysis. To make this possible, certain requirements as to number of experimental treatments and replications, as well as in field arrangement, must be met. The designs cannot be arranged for every combination.

Incomplete block designs are adapted to a situation where a large number of experimental treatments (16 or more) must be compared and where field variation is important. Where real differences occur between the small blocks, they are likely to show a gain in efficiency over simpler designs. With many treatments under consideration, a few may often be added or omitted to make up sets without injuring the experiment. Many types of

such designs are possible; the several "lattice" types, lattice squares, and balanced incomplete blocks are most widely used. These designs are well discussed as to construction and analysis by Yates (1936, 1937, 1939, 1940), Weiss & Cox (1939), Pope,[1] Cox *et al.* (1940). With the lattices and lattice squares, all plots of a given replication are kept together in a solid area (which is often not true of balanced incomplete blocks). In cases of experimental difficulties, results from these designs may be tentatively analyzed as though from ordinary randomized blocks. This makes these designs especially interesting, since they give a chance of improvement with little risk of loss of efficiency. In a problem to which they might be adapted, they can be recommended without hesitation. The lattice square accounts for field variation in two directions. It tends to be more precise than ordinary lattices (simple or triple), but its special restrictions make it harder to adapt to many problems. This is much like the comparison of ordinary Latin squares to randomized blocks.

APPLICATIONS TO ENTOMOLOGY.—In insect problems, the question of major interest is insect population. The density of population, and the proportion affected by some condition, are two questions that occur over and over. Some effect of insect activity correlated with population, such as injury to plants, may sometimes be used as an index or measure of population. Crop yields or stands associated with treatments, and other factors, are also of interest, but must be secondary, A number of insect problems are being studied by field-plot tests. Sometimes the insect observations are incidental to the work of the plant specialist, and are made on plots laid out for another major purpose. Plots may also be cooperatively developed. However, we have many cases in which they are laid out for entomological work alone. Where the conditions of many experimental treatments and considerable field variation occur, the ordinary lattice (simple or triple) or lattice square may be of help. The question may well be raised whether insect population does not tend strongly to distribute itself well through the field, and to show less local variation than does soil. We know from general experience, however, that some local variation in populations occurs.

RESULTS IN SEVERAL PRACTICAL EXPERIMENTS.—An experiment using a triple lattice design in testing insect resistance of barley varieties was carried out in 1942 by R. G. Dahms of the Bureau of Entomology and Plant Quarantine, at Lawton, Okla. Mr. Dahms had been working on the difficult problem of chinch bug resistance in barley. He had tested in a preliminary way several hundred varieties. It was agreed that replication must be used in later stages, that the number of varieties must be restricted to those which had shown promise, and that selection could easily be made to give 100 varieties. This use of a perfect square in number of varieties made it easy to lay out a triple lattice, and this was done. Chinch bug population was to have been the criterion. The experiment was interrupted by a "green bug" outbreak which injured the plots. Since this insect is sporadically important in the area, Mr. Dahms recorded data as to its attack on the plots. After trying several criteria, he found the percentage of leaves killed to be the best one. This reflects the preference of the insects for certain varieties and the varietal tolerance of their feeding. Results were recorded as percentages based on adequate and similar numbers from each plot, and practically all were between 10 and 90 per cent. Hence percentages were analyzed without modification.

The summary of analysis is as follows:

| | Degrees of Freedom | Mean Square | Mean Square by Random Complete Block Analysis |
|---|---|---|---|
| Between replications | 2 | 241 | 241 |
| Between varieties (ignoring blocks) | 99 | 526 | 526 |
| Blocks (adjusted) | 27 | 170 | — |
| Intra-block error | 171 | 48 | 65 |

Varietal averages are adjusted for a "t" test, according to the specific blocks in which they occur. Adjustments were not large, seldom over 2 per cent; 6 per cent was the maximum possible. Standard errors of mean differences are computed as 5.86 per cent for pairs of varieties occurring together in some block, and 5.96 per cent for others. (For the simple random block analysis the figure is 6.58 per cent.

[1] U.S.D.A. Grad. School, mimeographed, 1940.

Efficiency as compared with that from randomized complete blocks is estimated as in the neighborhood of 120 per cent. The three replications were nearly as good as four would have been with the simpler design.

The small blocks tended to show real differences reflecting local variation. The insects were migrants. It is sometimes true that incoming migrants distribute themselves widely but there is often some directional effect. Some varieties showed marked resistance.

A second opportunity to try one of these designs was afforded by experiments conducted by G. W. Barber and F. F. Dicke at Toledo, Ohio, in 1943 on varietal susceptibility of different strains of corn to the European corn borer. A large number of strains were to be tested. For several experiments, of about 50 to 150 varieties each, simple lattice designs were suggested. Borer population was to be the criterion. The device of artificial or manual infestation was to be used, to be sure of a good test. This, if it were the major source of infestation, would do away with much of the local field variation. However, natural infestation has been rising to important levels in this area and shows local variation. Reaction of plants to infestation may also show such variation. The lattice design would not be profitable if no local variation occurred, but carries very little risk of loss of efficiency as compared with complete blocks.

The season was an extraordinary one; May was exceptionally wet and no corn could be planted till June 8. Natural infestation was reduced by the lateness of the crop. All strains gave rather similar results, and few conclusions could be reached. Results of one experiment of 49 strains, replicated 4 times in a simple lattice, were sent in for study. The experimenters stated that this was as good as any of the tests in results. Plots included 5 plants each; total borers were from 7 to 20 per plot. Unmodified counts are used in analysis. Transformation might be believed to be needed, but tentative analysis of logarithms failed to show any change in results.

The summary of analysis is given in table 1. No significant differences and no gain in efficiency for the lattice could be detected. The replication areas showed some differences. The small blocks showed a tendency to differ, but with plots as small as these and the somewhat abnormal conditions of the year the use of small blocks gave no benefit.

**Table 1**

| | Degrees of Freedom | Mean Square | Mean Square as Random Complete Blocks |
|---|---|---|---|
| Between replications | 3 | 276.0 | 276.0 |
| Between strains (ignoring blocks) | 48 | 24.4 | 24.4 |
| Between blocks (eliminating strains) | 24 | 41.3 | — |
| Intra-block error | 120 | 24.1 | 27.0 |

In two replications the plots had additional plants subjected to natural infestation only. These were analyzed separately, as shown in Table 2.

**Table 2**

| Source of Variation | Degrees of Freedom | Mean Square |
|---|---|---|
| Replications | 1 | 420.5 |
| Strains (ignoring blocks) | 48 | 45.6 |
| Blocks (eliminating strains) | 12 | 74.1 |
| Error (intra-block) | 36 | 28.8 |

The tendency to show strain and block differences seemed greater, and a slight gain in efficiency is suggested, although significant strain differences did not appear.

It may be of interest to add that the plots manually infested in these two replications showed a difference approaching significance, when adjusted by covariance for natural infestation. The difference in reaction to artificial infestation alone is shown by this test.

A third test of incomplete block designs was made in 1944 in cotton insect work, by C. F. Rainwater at the Florence, S. C., laboratory of the Bureau. There were 16 insecticidal treatments arranged in a lattice square with 5 replications. The criteria were percentage of squares attacked by the weevil, aphids per leaf (of standard position on the plant), and crop yield. The experiment went off smoothly. Boll weevil population was rather low and aphid populations moderate. Yield was not very variable and was not affected significantly by treatments. Insect counts were made at intervals through the

summer, but the three made in August were averaged for analysis. At the time of these counts the treatment effects had had time to show up. Both percentage of squares attacked and aphid counts were in a range which could well be analyzed without transformation.

Analysis by the method discussed by Weiss & Cox (1939) based on Yates' earlier work failed to show much gain in efficiency over randomized complete blocks; but analysis by Yates' method (1940b), with recovery of inter-block information, showed a moderate gain with the insect populations. This may be expected, especially with cases of $n+1$ replications. Analysis is shown in table 3.

**Table 3**

| Source of Variation | | Degrees of Freedom | Mean Square: Aphid population | Mean Square: Boll weevil attack |
|---|---|---|---|---|
| | Squares | 4 | 293.6 | 7.9 |
| | Treatments | 15 | 1012.6 | 90.3 |
| Not fully additive | Rows, eliminating trtmt. | 15 | 91.3 | 73.8 |
| | Columns eliminating trtmt. | 15 | 21.7 | 42.9 |
| | Rows, elim. trtmt. & col. | 15 | 93.6 | 68.9 |
| | Columns, elim. trtmt. & rows | 15 | 24.0 | 37.9 |
| | Error | 30 | 57.9 | 18.2 |

Adjustment factors were computed for treatments and did not give large shifts. With the boll weevil attack, significant differences appeared, though they were not marked, by analysis either as above or as complete blocks. The lattice-square analysis gave a little greater discrimination. With aphid population, marked differences betweeen treatments appeared. Using complete block analyses or the earlier lattice-square method, the differences recognizable were limited to those between two groups of treatments, having high and low populations. Using Yates' 1940 method, some discrimination within each group was possible. The efficiency gain as compared with that from complete blocks was estimated as about 15 per cent for aphid population, and near 50 per cent for the boll weevil. The lattice square gave a gain equivalent to that obtainable from 1 or 2 additional replications with complete blocks.

CONCLUSIONS.—It seems from these preliminary trials that insect populations and their activities tend to vary locally, and that there is a chance for some improvement in precision from use of incomplete block designs. The improvement so far has been moderate; a gain of efficiency equivalent to that obtainable from addition of another replication, in ordinary tests, is suggested as likely. Where crop yield is a criterion also, it may show on variable soil more improvement than this. These designs evidently deserve consideration in insect problems when large numbers of treatments are to be tried in field plots.

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## SIXTH ANNUAL SOUTHERN PCO CONFERENCE

The sixth annual conference of the Southern Pest Control Operators is scheduled to be held at Louisiana State University, at Baton Rouge, on February 14, 15 and 16.

# Compatibility of Cryolite and Copper Fungicides

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Cryolite, sodium fluoaluminate, has found more extended usage in the past two years than heretofore as an alternative insecticide to replace rotenone bearing sprays and dusts. The insecticidal value of cryolite and its uses for insect control have been reviewed by Marcovitch & Stanley (1942) who conclude that this material has marked advantages over the arsenicals. They caution, however, that cryolite should not be used with strong alkalis or acids as chemical changes may reduce toxicity to insects or result in plant injury.

For pest control on many plants it is advantageous to use a combination of insecticide and fungicide. Compatibility of the two is a requisite for proper protection. Since specific information on the compatibility of cryolite and copper fungicides seemed to be lacking, laboratory and field studies were made on combinations of cryolite and the more common fungicides used in disease control.

MATERIALS AND METHODS.—The Mexican bean beetle was the test insect used in the laboratory studies utilizing the technique described in an earlier paper (Wene & Hansberry 1944). Only brief mention need be made of the testing procedure as the methods used are well standardized.

The combination of cryolite and copper fungicide was sprayed on the underside of bean leaves and allowed to dry thoroughly before the leaves were placed, sprayed side up, in culture dishes. Bean beetle larvae of one age group were transferred to the dishes and allowed to feed for certain specified periods depending on the intent of the experiment. Mortality records were taken at daily intervals at which time the leaves were replaced with fresh ones.

Micronized natural cryolite (*Kryocide*) containing at least 90 per cent sodium fluoaluminate was combined in water suspension with the coppers shortly before use. The mixtures were not allowed to stand for more than 30 minutes. The concentrations of copper corresponded to those generally used in the field or recommended by the manufacturer. Copper contents of the various spray mixtures, therefore, varied considerably but in no case was there less than one pound of metallic copper per 100 gallons of spray.

Readings of the pH of the fungicide suspensions were taken before and after addition of the cryolite. Fixed copper sprays read very close to the neutral point whereas bordeaux mixture was very basic in reaction. The addition of cryolite slightly reduced the pH values, but not

**Table 1.—The mortality of Mexican bean beetle larvae feeding for 5 days on bean leaves sprayed with mixtures of cryolite and copper fungicides.**

| 6 LBS. CRYOLITE IN 100 GAL. $H_2O$ PLUS | PER CENT MORTALITY IN DAYS | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | | *Third Instar* | | | | |
| 1.5 lbs. *Yellow Cuprocide*[1] | 9.0 | 17.0 | 45.5 | 78.7 | 94.0 | 100.0 | 100.0 |
| 6 lbs. *C O C S* | 3.0 | 8.0 | 33.3 | 74.5 | 96.4 | 100.0 | 100.0 |
| 3 lbs. *Spraycop* | 15.0 | 30.0 | 62.6 | 95.7 | 98.8 | 100.0 | 100.0 |
| 3 lbs. *Basi cop* | 24.0 | 35.0 | 54.5 | 86.2 | 95.2 | 98.6 | 98.2 |
| 10-10-100 bordeaux | 0.0 | 0.0 | 3.0 | 41.5 | 69.0 | 92.0 | 93.7 |
| 10-5-100 bordeaux | 0.0 | 0.0 | 7.1 | 39.4 | 58.3 | 88.4 | 95.2 |
| *Kryocide* (alone) | 22.0 | 37.0 | 36.4 | 88.3 | 95.2 | 100.0 | 100.0 |
| | | | *Fourth Instar* | | | | |
| 1.5 lbs. *Yellow Cuprocide* | 1.0 | 4.0 | 0.0 | 32.6 | 59.5 | 69.5 | 73.4 |
| 6 lbs. *C O C S* | 0.0 | 1.0 | 0.0 | 39.3 | 67.9 | 79.3 | 86.1 |
| 3 lbs. *Spraycop* | 0.0 | 5.0 | 12.9 | 31.5 | 67.9 | 84.1 | 89.9 |
| 3 lbs. *Basi cop* | 1.0 | 10.0 | 16.1 | 41.6 | 65.5 | 75.6 | 82.3 |
| 10-10-100 bordeaux | 0.0 | 0.0 | 0.0 | 0.0 | 25.0 | 63.4 | 69.6 |
| 10-5-100 bordeaux | 0.0 | 2.0 | 0.0 | 0.0 | 32.1 | 59.8 | 60.8 |
| *Kryocide* (alone) | 3.0 | 9.0 | 17.2 | 37.1 | 63.1 | 72.0 | 81.0 |

[1] *Yellow Cuprocide*—Rohm and Haas; *COCS*—Niagara Sprayer and Chemical Company; *Spraycop*—General Chemical Company; *Basi cop*—Sherwin Williams; *Kryocide*—Pennsylvania Salt Mfg. Company.

**Table 2.—The mortality of Mexican bean beetle larvae feeding 1, 3 and 5 days on bean leaves sprayed with a mixture of cryolite and copper fungicides.**

| 6 lbs. *Kryocide* in 100 Gal. $N_2O$ Plus | Days of Feeding | Per Cent Mortality in Days | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | *Third Instar* | | | | | | |
| 1.5 lbs. *Yellow Cuprocide* | 1 | 11.0 | 18.0 | 33.0 | 42.0 | 43.4 | 45.1 | 39.0 |
| 3 lbs. *Spray cop* | 1 | 4.0 | 11.0 | 27.0 | 44.0 | 45.0 | 47.8 | 46.2 |
| 10-10-100 bordeaux | 1 | 0.0 | 0.0 | 0.0 | 1.0 | 3.0 | 1.0 | 0.0 |
| *Kryocide* (alone) | 1 | 12.0 | 17.0 | 30.0 | 41.0 | 47.5 | 50.0 | 47.6 |
| 1.5 lbs. *Yellow Cuprocide* | 3 | 14.0 | 21.0 | 41.0 | 76.0 | 81.8 | 84.3 | 84.1 |
| 3 lbs. *Spraycop* | 3 | 4.0 | 7.0 | 34.0 | 65.0 | 77.8 | 77.1 | 76.8 |
| 10-10-100 bordeaux | 3 | 0.0 | 1.0 | 2.0 | 6.0 | 10.1 | 9.6 | 0.0 |
| *Kryocide* (alone) | 3 | 20.0 | 34.0 | 50.0 | 70.0 | 76.8 | 78.1 | 74.3 |
| 1.5 lbs. *Yellow Cuprocide* | 5 | 9.0 | 17.0 | 45.5 | 78.7 | 94.0 | 100.0 | 100.0 |
| 3 lbs. *Spraycop* | 5 | 15.0 | 30.0 | 62.6 | 95.7 | 98.8 | 100.0 | 100.0 |
| 10-10-100 bordeaux | 5 | 0.0 | 0.0 | 3.0 | 41.5 | 69.0 | 92.0 | 93.7 |
| *Kryocide* (alone) | 5 | 22.0 | 37.0 | 36.4 | 88.3 | 95.2 | 100.0 | 100.0 |
| | | *Fourth Instar* | | | | | | |
| 1.5 lbs. *Yellow Cuprocide* | 1 | 0.0 | 2.0 | 2.0 | 0.0 | 13.5 | 6.4 | 23.2 |
| 3 lbs. *Spraycop* | 1 | 0.0 | 1.0 | 3.1 | 0.0 | 0.0 | 0.0 | 2.4 |
| 10-10-100 bordeaux | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.5 |
| *Kryocide* (alone) | 1 | 1.0 | 4.0 | 3.1 | 0.0 | 14.6 | 12.0 | 28.0 |
| 1.5 lbs. *Yellow Cuprocide* | 3 | 0.0 | 2.0 | 4.0 | 14.3 | 28.1 | 34.9 | 35.4 |
| 3 lbs. *Spraycop* | 3 | 1.0 | 5.0 | 8.2 | 16.5 | 30.3 | 31.3 | 40.5 |
| 10-10-100 bordeaux | 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 |
| *Kryocide* (alone) | 3 | 3.0 | 14.0 | 21.4 | 29.7 | 37.1 | 44.6 | 51.1 |
| 1.5 lbs. *Yellow Cuprocide* | 5 | 0.0 | 4.0 | 4.1 | 17.6 | 47.1 | 66.3 | 69.5 |
| 3 lbs. *Spraycop* | 5 | 0.0 | 1.0 | 3.1 | 22.0 | 40.4 | 66.3 | 70.7 |
| 10-10-100 bordeaux | 5 | 0.0 | 1.0 | 0.0 | 0.0 | 11.2 | 38.6 | 40.2 |
| *Kryocide* (alone) | 5 | 2.0 | 7.0 | 14.1 | 37.4 | 58.4 | 75.9 | 81.7 |

enough to produce marked changes in the mixtures.

As a precautionary measure spray deposits were checked to detect possible discrepancies due to effects of the various ingredients on spray delivery. No significant differences were noted between deposits; the average calculated amount of cryolite approximated .03 mg. per square centimeter of area.

A single field experiment was conducted on potatoes for control of the Colorado potato beetle, *Leptinotarsa decemlineata*. The spray combinations were applied with field equipment at the time infestations were near peak. Mortality was estimated by counting dead and living larvae at random stations in each plot.

Results and Discussion.—Toxicity of cryolite with copper fungicides to third and fourth instar larvae of *Epilachna varivestis* was determined in separate series of tests. A total of 100 individuals divided into four replicates were used for testing each combination. The larvae were allowed to feed on sprayed foliage for 5 days, then transferred to unsprayed leaves for the remaining days of the test period. The data have been adjusted by means of Abbott's formula to correct for mortality in the check series; hence occasional discrepancies appear in the accumulative death toll from day to day.

It is evident from the data (Table 1) that cryolite is a slow acting poison requiring 3 to 5 days to produce more than 50 per cent mortality of third and fourth instars respectively. Previous to the fifth day of the experimental period apparent differences exist among the fixed copper-cryolite combinations. These differences apparently are of little significance since mortalities are about equal on the fifth day for all combinations except cryolite-bordeaux. The accumulative mortalities for the cryolite-bordeaux mixture was less during the entire period of the experiment being particularly pronounced during the first 3 days. While the addition of bordeaux to cryolite does not completely destroy its toxicity, its action is definitely delayed and a longer time is required for

a specified kill than in the case of the fixed coppers.

That some changes occur in the cryolite-bordeaux mixture thereby adversely affecting its toxicity seem evident from a percursory examination of the leaf tissues consumed by the larvae in the various series. Considerably more feeding was noted on leaves sprayed with cryolite-bordeaux than in the case of any other combination. In proportion to the amounts ingested, therefore, the cryolite-bordeaux coating was not as toxic as the other combinations.

This is more clearly indicated in a second series of experiments in which the lengths of the feeding periods were varied from 1 to 5 days. The larvae were allowed to feed on sprayed foliage for prescribed lengths of time and then were transferred to untreated leaves. Noting the data in table 2, the mortality of larvae feeding on cryolite-bordeaux sprayed foliage for 1 or 3 days is seen to be approximately equal to the checks whereas kills with the other cryolite combinations were considerably higher. A very pronounced increase in kill was obtained when larvae continued to feed on cryolite-bordeaux sprayed foliage for 5 days although mortalities in this treatment series were less than in case of the other combinations.

The data obtained from the field experiment substantiated the laboratory results except that Colorado potato beetle larvae were more susceptible to cryolite poisoning than bean beetle larvae. The mortality from the cryolite-bordeaux mixture was less at the 24-hour period following application than the kills of the other two combinations (Table 3), but the count taken on the third day indicated little or no difference between combinations. Bordeaux seemed to delay toxic action rather than reduce the toxicity of the cryolite used with it. No measure of the amount of foliage consumed by the larvae after spray appplications could be taken; therefore, no indication of differences in injury between treatments is possible.

Table 3.—Comparison of the toxicity of cryolite when used with fixed coppers and bordeaux mixture for control of the Colorado potato beetle.

| | Per Cent Mortality in Days | | |
|---|---|---|---|
| Cryolite[1] Plus | 1 | 2 | 3 |
| Yellow *Cuprocide* | 60 | 65 | 74 |
| Tennessee Tribasic | 59 | 66 | 81 |
| Bordeaux 8–4–100 | 21 | 60 | 72 |

[1] *Alorco* synthetic cryolite 6 lbs. per 100 gallons.

SUMMARY.—Combining a number of commercial fixed copper compounds with natural cryolite (*Kryocide*) did not adversely affect the toxicity of the latter to third and fourth instar Mexican bean beetle larvae. Bordeaux delayed and decreased toxic action but did not make the cryolite impotent. Considerably more feeding was evident on bean leaves sprayed with cryolite-bordeaux than in the case of the cryolite-fixed copper combinations. Evidence thus points to the possibility of a change in the cryolite when combined with bordeaux, a change that is not evident in the fixed copper mixtures.

In a single field experiment for control of the Colorado potato beetle bordeaux delayed toxic action of the cryolite, but did not materially reduce final mortality in comparison with kills obtained by two fixed copper combinations.—11-26-45.

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## DR. W. E. DOVE

Dr. W. E. Dove has resigned his position with the Bureau of Entomology and Plant Quarantine where he was in charge of investigations dealing with insects affecting man and domestic animals and has joined the staff of Dodge and Olcott of New York. Dr. Dove will be in charge of the research program in entomology sponsored by this firm.

# Modification of the Geraniol and Eugenol Content of Japanese Beetle Bait

MARTIN H. MUMA, GEORGE S. LANGFORD, and ERNEST N. CORY

The war has so upset the normal supplies of geraniol and eugenol, the attractants used in the present beetle bait, that some modification of the old formula is essential. The cost of both geraniol and eugenol is becoming prohibitive for use on the same basis as in the past. Supplies of geraniol are already limited, and the prospects of obtaining the grade desired is uncertain. Satisfactory relief will probably not come until after the war.

For several years studies have been conducted at the University of Maryland on materials attractive to the Japanese beetle. Since 1942 and after the war threatened normal supplies, intensive studies have been made to find substitutes for the geraniol and eugenol combination. While it has not been possible, as yet, to entirely eliminate both of these materials, effective baits have been prepared by drastic modification of the old formula. This has been accomplished by the use of white mineral oils as diluents in geraniol-eugenol mixtures and by utilizing or substituting in the mixture other known attractants.

METHODS.—The attractiveness of all baits was studied under field conditions in standardized Japanese beetle traps. All equipment, other than bait, was identical in each test. The traps were spaced 10 feet apart in linear batteries. Each battery was composed of one trap containing the standard formula, one empty and three to four containing test baits. The size of the batteries was uniform for each test and batteries usually were replicated three times. All traps in each battery were rotated daily to overcome the effects of masking and trap location.

The geraniol-eugenol bait has been designated as the standard formula and in these studies consisted of a nine to one mixture. The mineral oil diluents used were *Deobase* oil and light white mineral oil (Saybolt viscosity 125 to 135). In all dilutions of geraniol-eugenol baits equal parts of these oils were used as this mixture approached the evaporation rate of the standard. In order to stabilize and reduce the evaporation rate of the very volatile materials, caproic acid, ethyl caproate and phenyl ethyl butyrate were diluted fifty percent with light white mineral oil before being mixed in baits.

MINERAL OILS AS DILUENTS.—Data published by the authors in 1944 indicated that the standard bait, consisting of 9 parts of geraniol and 1 part of eugenol, could be diluted up to 50 per cent with equal parts of *Deobase* oil and light white mineral oil without materially affecting efficiency. Results this past season substantiated this finding. Over a period of 7 weeks 100 replications each of 30 and 50 per cent diluted bait compared with 100 replications of standard had total beetle catches as follows: 30 per cent dilution 424,037; 50 per cent dilution 428,929, and standard (not diluted) 439,688.

The possibility of modifying the standard bait by changing the proportion of geraniol to eugenol was demonstrated first by Fleming & Burgess in 1940. They pointed out that if the eugenol content was increased a more attractive bait was obtained. However the cost of eugenol at that time in comparison with that of geraniol necessitated a balance of economics against efficiency. Under present conditions the cost of geraniol exceeds that of eugenol, thus making it economical to increase the eugenol content in bait.

Research by the authors indicated that equal parts of geraniol and eugenol made an effective bait and that dilution up to 50 per cent with *Deobase* and light white mineral oil, was feasible. On the basis of this work, and as an economy means, a bait consisting of equal parts of geraniol and eugenol diluted 30 per cent with equal parts of *Deobase* oil and light white mineral oil was used for field work in approximately 50,000 traps in Maryland in 1944. Comparative tests substantiated the attractiveness of this modified bait. Thirty replications of modified bait compared with 30 of the standard showed a 40.2 per cent increase in attractiveness for the modified bait. The traps containing the modified bait caught a total of 32,778 beetles as compared with 23,372 beetles for traps with the standard.

**Table 1.—Comparative efficiency of modified Japanese beetle bait formulae for conserving and replacing geraniol and eugenol.**

| | BEETLES ATTRACTED | PER CENT OF STANDARD |
|---|---|---|
| *Diluted Standards* | | |
| Oil mixture 3 parts—Standard 7 parts | 424,037 | 96.4 |
| Oil mixture 5 parts—Standard 5 parts | 428,926 | 97.5 |
| Standard (no dilution) | 439,688 | 100.0 |
| *Modified Standard Diluted* | | |
| Oil mixture 3 parts—Geraniol-Eugenol mixture (50–50) 7 parts | 32,778 | 104.2 |
| Standard | 23,372 | 100.0 |
| *Substitute Attractants* | | |
| Caproic acid and oil (50–50) 9 parts—Standard bait 1 part | 22,850 | 104.3 |
| Caproic acid and oil 9 parts—Geraniol 1 part | 23,318 | 106.5 |
| Caproic acid and oil 9 parts—Eugenol 1 part | 17,613 | 80.5 |
| Standard | 21,887 | 100.0 |
| Phenyl ethyl butyrate and oil 9 parts—Standard 1 part | 25,093 | 95.7 |
| Phenyl ethyl butyrate and oil 9 parts—Geraniol 1 part | 20,084 | 76.6 |
| Phenyl ethyl butyrate and oil 9 parts—Eugenol 1 part | 16,248 | 61.9 |
| Standard | 26,207 | 100.0 |
| Ethyl caproate and oil 9 parts—Standard 1 part | 24,023 | 80.3 |
| Ethyl caproate and oil 9 parts—Geraniol 1 part | 20,702 | 69.2 |
| Ethyl caproate and oil 9 parts—Eugenol 1 part | 18,560 | 57.8 |
| Standard | 29,911 | 100.0 |
| Anethol 9 parts—Standard 1 part | 27,012 | 76.6 |
| Anethol 9 parts—Geraniol 1 part | 18,071 | 51.2 |
| Anethol 9 parts—Eugenol 1 part | 29,333 | 83.2 |
| Standard | 35,241 | 100.0 |
| Citral 9 parts—Standard 1 part | 29,188 | 71.7 |
| Citral 9 parts—Geraniol 1 part | 15,126 | 37.1 |
| Citral 9 parts—Eugenol 1 part | 25,130 | 61.7 |
| Standard | 40,701 | 100.0 |

OTHER ATTRACTANTS IN THE GERANIOL-EUGENOL MIXTURE.—Work at the University of Maryland has shown that many chemicals including certain alcohols, acids, esters and oils were attractive to the beetle. In 1943 Langford *et al.* pointed out that some attractants when mixed had an additive value, several even exceeding the sum of attractive values of the constituents. Several attractants have given favorable results when used in combination with either or both geraniol and eugenol. Caproic acid, ethyl caproate, phenyl ethyl butyrate, anethol and citral all show good attractive values when mixed in a ratio of nine to one, with either geraniol, eugenol or standard bait.

Caproic acid, ethyl caproate and phenyl ethyl butyrate are quite volatile and it is essential that their rate of evaporation be reduced. In these studies this was accomplished by mixing with equal parts of light white mineral oil.

Caproic acid stabilized with oil was the most effective of the materials tested. When mixed at a ratio of nine to one with either geraniol alone, or with standard bait it had an attractive value equivalent to or greater than the standard. Mixtures in the same ratio with eugenol were less attractive. They were about 80 per cent as attractive as standard bait.

The esters, phenyl ethyl butyrate and ethyl caproate, when used at the ratio of nine to one with standard bait compared quite favorably to standard. There was some fluctuation between comparative values in different locations, but the variation was well within that obtained with the standard. Phenyl ethyl butyrate was the most attractive of the two materials. When mixed with standard it gave comparative values that varied between 89.2 per cent and 112.7 per cent on the basis of 100 per cent for the standard. Ethyl caproate varied from 70.5 per cent to 105.4 per cent. With geraniol the average values were 76.6 per cent for phenyl ethyl butyrate and 69.2 per cent for ethyl caproate. Results with eugenol were not

consistent, location seeming to materially affect comparative values. Eugenol mixtures of esters appeared to be most attractive when used in the vicinity of favored food plants. The value for ethyl caproate was 93.4 per cent while that for phenyl ethyl butyrate was 98.7 per cent. In a series isolated from favored food the values for both materials fell to 49.8 per cent. The average values were 61.9 per cent for phenyl ethyl butyrate and 57.8 per cent for ethyl caproate.

Fleming & Chisholm (1944) recently suggested anethol as a substitute for geraniol in Japanese beetle bait. This material is decidedly promising as a replacement for geraniol. Used with eugenol its attractive value was 83.2 per cent. It was not sufficiently attractive for practical consideration when combined with geraniol alone, but when combined with standard bait the attractive value was 76.6 per cent.

Citral, an optical isomer of geraniol, although not as effective a replacement material as either caproic acid or anethol had an attractive value of 71.7 per cent of the standard when mixed at a nine to one ratio with the standard. Its attractive value with eugenol was 61.7 per cent.

SUMMARY.—Studies on the modification of the present Japanese beetle bait formula with the objective of conservation or the replacement of the present limited and costly supplies of geraniol and eugenol, particularly geraniol, indicate that this may be partly accomplished in three ways. First, the present bait, composed of geraniol and eugenol, may be diluted fifty per cent with equal parts of *Deobase* oil and light white mineral oil. This dilution does not materially affect the attractive qualities of the bait. Second, the present ten to one ratio of geraniol and eugenol may be shifted to a one to one mixture which may be diluted thirty per cent with mineral oils causing no reduction in attractive value. Third, substitute materials may be used to replace all or nearly all of the geraniol in the mixture. Of the substitutes tested caproic acid and anethol were quite effective, with citral somewhat less desirable. Two esters: ethyl caproate and phenyl ethyl butyrate show possibilities and may prove efficient.

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## NOTICE

Commission for the Study of the Damage caused to Entomology by War.

Commission pour l'Étude des Dammages causes par la Guerre a l'Entomologié.

HERBERT OSBORN, *The Ohio Biological Survey*
and
JEAN LECLERQ, *Université de Liége*

TO DIRECTORS OF ENTOMOLOGICAL LABORATORIES, MUSEUMS AND INSTITUTIONS

Has your Institution suffered from war:

(1) By loss or damage of materials such as destruction of housing, of apparatus, of collections or entomological books of value?
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Have you, due to act of war, had to interrupt publications?
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Reply to M. JEAN LECLERQ
*Université de Liége 17, place Delcour Liége (Belgium)*

# A New Chlorinated Hydrocarbon Insecticide

C. W. KEARNS and LESTER INGLE, *University of Illinois*, and
ROBERT L. METCALF, *Tennessee Valley Authority*

A chlorinated hydrocarbon having the empirical formula $C_{10}H_6Cl_8$[1] has been found to be more toxic than DDT[2] and to compare favorably in toxicity to the pure $\gamma$ isomer of benzenehexachloride (Taylor 1945) to a number of species of insects. This compound which will hereafter be referred to as "*1068*" is possibly a mixture of isomers which as yet have not been resolved and evaluated individually. A more complete description of the chemical structure will be presented in the near future as soon as certain features have been clarified. Meanwhile, the remarkable toxicity of the material and the possibility of its immediate use as an insecticide have prompted us to report on the insecticidal properties of *1068*. The purpose of this paper is to report laboratory tests with *1068* on several species of insects which will serve to indicate a few of its possible fields of usefulness. For comparative purposes parallel tests have been made with DDT and in some cases $\gamma$-benzenehexachloride.

The compound can be isolated readily as a viscous, colorless, odorless liquid boiling at 175° C. at 2 mm. pressure. This liquid which is at least 99 per cent pure has shown no tendency to be irritating to the skin or mucous membranes. The compound *1068* is readily soluble in all proportions in most organic solvents such as aromatic, aliphatic, and chlorinated hydrocarbons, ketones, ethers, esters, and alcohols but is insoluble in water. Of unusual interest is the complete miscibility of the material with deodorized kerosene commonly used in insecticide formulations. Like DDT and $\gamma$-benzenehexachloride *1068* has the property of dehydrohalogenating readily in the presence of weak alkali to form a product which apparently is non-toxic to insects. For this reason it should be considered incompatible with materials having an alkaline reaction. It has low volatility, being intermediate between DDT and $\gamma$-benzenehexachloride.

The compound, *1068*, may be formulated for insecticidal use as an oil solution, an oil emulsion, a dust, or a dispersible liquid. Nearly any type of suitable oil carrier may be used to make a solution of *1068* of any desired strength because of its miscibility. Solvents which are most convenient are kerosene, deobase, fuel oil, xylene, and methylated naphthalenes. The addition of small amounts of oil-soluble emulsifiers such as *Triton-X-100*, *Duponol OS*, or *Atlas G1036* to such oil solutions makes emulsion concentrates to which may be added any desired amount of water. Also *1068* may be emulsified directly in water by the addition of a soluble emulsifier; however, in this case higher percentages of emulsifier must be used. Dusts containing 5 per cent or less of active ingredient can be prepared by impregnating the material on talc, clays, or other non-alkaline carriers.

Table 1.—Comparative toxicity of *1068* and DDT to *Aphis spiraecola*.

| Compound | Dilution gm./ml. | No. of Tests | No. of Aphids | Per Cent Mortality 24 Hours |
|---|---|---|---|---|
| *1068* | 1–800 | 2 | 311 | 100 |
| DDT | 1–800 | 2 | 231 | 91 |
| *1068* | 1–1000 | 4 | 859 | 97 |
| DDT | 1–1000 | 4 | 734 | 88 |
| *1068* | 1–1200 | 2 | 262 | 97 |
| DDT | 1–1200 | 2 | 237 | 78 |
| *1068* | 1–2000 | 4 | 974 | 95 |
| DDT | 1–2000 | 4 | 691 | 76 |
| *1068* | 1–4000 | 6 | 894 | 91 |
| DDT | 1–4000 | 6 | 890 | 66 |
| *1068* | 1–6000 | 2 | 180 | 95 |
| DDT | 1–6000 | 2 | 232 | 47 |
| *1068* | 1–8000 | 2 | 260 | 86 |
| DDT | 1–8000 | 2 | 261 | 49 |
| Control[1] | | 6 | | 00 |

[1] A solution of 3 parts acetone and 1 part water.

Unless otherwise specified in the text, the insecticidal materials used were all chemically pure. The melting point of the DDT (2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane) used was 105–108° C.; the melting point of the $\gamma$-benzenehexachlo-

[1] Velsicol Corporation, Chicago, Illinois, U.S.A. Patents pending.
[2] Geigy Company, Inc., New York City, U.S. Patent. No. 2,329,074.

ride was 110 to 112° C., and the sample of *1068* was a clear liquid boiling at 175° C. at 2 mm. pressure.

The tests were made by standard entomological procedures as are detailed herein. The methods and formulations selected for any given species were those which appeared to give the least variable results, while at the same time approximating actual field control methods.

APHID TESTS.—It was found by preliminary trials that both DDT and *1068* are readily dispersible in a 75 per cent acetone water solution and that this solution without the active compounds could be applied to aphids in sufficient quantity to wet them thoroughly without causing any mortality. The tests reported in table 1 on the spiraea aphid (*Aphis spiraecola* Patch) were made by treating infested terminal sections of the plant with approximately 5 ml. of atomized spray mixture. The cut ends of the treated infested twigs were then placed in a vial of water and stoppered with cotton to prevent the aphids from falling into it. Mortality counts made 24 hours after treatment were based only on the mature wingless forms which were found both on the plant and on a tanglefoot bordered paper upon which the treatments were placed. Any insects able to move when lightly touched with a camel's hair brush were counted as being alive.

Pea aphid (*Macrosiphum pisi*) tests made in the same manner produced results so variable as to make the method unusable. This may have been due to considerable heterogeneity in the culture, effects of plant on spray deposition, or other factors. Less variable results were obtained by removing wingless adult aphids from the plant and spraying them on cheesecloth stretched over embroidery hoops. After the spray had dried the aphids were transferred to previously sprayed pea leaves and confined in a moist chamber.

The results of tests on the spiraea aphid (Table 1) and pea aphid (Table 2) show that *1068* is several times more toxic than DDT to these insects. It would seem that the pea aphid is the more resistant of the two species to both DDT and *1068*.

TESTS WITH COLORADO POTATO BEETLE LARVAE, *Leptinotarsa decemlineata* Say.—Potato leaves were sprayed with the active compounds dispersed in a solution of three parts acetone and one part water. The leaves were allowed to dry and the untreated larvae placed on them and maintained in a moist chamber for the duration of the test period. In these tests, the results of which are shown in table 3, most of the mortality resulted from contact with the treated foliage. Apparently *1068* acted as a greater deterrent to feeding than did DDT as is shown by the relative amounts of foliage consumed, but this may in part be due to its greater toxicity.

**Table 2.—Comparative toxicity of *1068* and DDT to the pea aphid.[1]**

| COMPOUND | DILUTION gm./ml. | PER CENT MORTALITY 24 HOURS | PER CENT MORTALITY 48 HOURS |
|---|---|---|---|
| *1068* | 1–250 | 97 | 100 |
| DDT | 1–250 | 60 | 80 |
| *1068* | 1–500 | 91 | 100 |
| DDT | 1–500 | 68 | 89 |
| *1068* | 1–1000 | 85 | 94 |
| DDT | 1–1000 | 42 | 80 |
| *1068* | 1–2000 | 76 | 90 |
| DDT | 1–2000 | 21 | 65 |
| *1068* | 1–4000 | 61 | 91 |
| DDT | 1–4000 | 20 | 35 |
| Control[2] | | | 00 |

[1] Three tests, each containing 20 aphids were made with each dilution.
[2] A solution of 3 parts acetone and 1 part water.

TESTS ON ADULT SQUASH BUGS, *Anasa tristis* Deg.—The results presented in table 4 are for the most part self-explanatory both in methods and results. They show that DDT even though applied in various ways is relatively ineffective to the adult squash bug, whereas *1068* is markedly effective regardless of the method of application.

RESIDUAL TOXICITY TESTS TO ANOPHELINE MOSQUITOES.—The residual toxicities of *1068*, DDT, and benzenehexachloride were compared by applying to 6-inch squares of wallboard the materials as emulsified xylene solutions containing 5 per cent of the active compounds. These were tested for toxicity at intervals by confining 2-day old female *Anopheles quadrimaculatus* under half petri dishes so that the insects were forced to contact the treated surfaces. At least 20 female insects were used in each test and the time re-

**Table 3.—Comparative toxicity of *1068* and DDT to the Colorado potato beetle larva.[1]**

| Compound | Dilution gm./ml. | Per Cent Mortality 24 Hours | Per Cent Mortality 48 Hours | Per Cent Mortality 72 Hours | Relative Amounts Foliage Consumed |
|---|---|---|---|---|---|
| *1068* | 1–500 | 40 | 80 | 100 | none |
| DDT | 1–500 | 00 | 30 | 80 | + |
| *1068* | 1–1000 | 20 | 50 | 90 | + |
| DDT | 1–1000 | 0 | 40 | 60 | ++ |
| *1068* | 1–2000 | 0 | 30 | 80 | + |
| DDT | 1–2000 | 0 | 20 | 20 | ++ |
| *1068* | 1–4000 | 0 | 20 | 60 | + |
| DDT | 1–4000 | 0 | 20 | 30 | +++ |
| Control[2] | | | | 00 | ++++ |

[1] Three tests, each containing 10 third or fourth instar larvae, were made at each dilution.
[2] A solution of 3 parts acetone and 1 part water.

**Table 4.—Comparative toxicity of *1068* and DDT to the adult squash bug.[1]**

| Compound | Dust Per Cent Conc. | Mgs. Dust Deposit sq. cm. | Dilution gm./ml. | Per Cent Mortality 24 hours | 48 hours | 72 hours |
|---|---|---|---|---|---|---|
| A. *1068* | 5 | .45 | | 38 | 75 | 100 |
| DDT | 5 | .52 | | 0 | 13 | 26 |
| *1068* | 4 | .45 | | 26 | 73 | 100 |
| DDT | 4 | .62 | | 0 | 0 | 13 |
| *1068* | 3 | .60 | | 38 | 75 | 88 |
| DDT | 3 | .51 | | 0 | 13 | 13 |
| *1068* | 2 | .60 | | 25 | 75 | 88 |
| DDT | 2 | .55 | | 0 | 13 | 13 |
| Talc | | .58 | | 0 | 0 | 0 |
| B. *1068* | 2 | | | 75 | 100 | |
| DDT | 2 | | | 0 | 25 | 25 |
| Talc | | | | 0 | 0 | 0 |
| C. *1068* | | | 1–1500 | 25 | 50 | 75 |
| DDT | | | 1–1500 | 0 | 0 | 0 |
| Control[2] | | | | 0 | 0 | 0 |
| D. *1068* | | | 1–1500 | 75 | 100 | |
| DDT | | | 1–1500 | 0 | 25 | 25 |
| Control[2] | | | | 0 | 0 | 0 |

A. Leaves dusted on upper surface in dust tower (Waters, 1937) and untreated squash bugs placed on leaves.
B. Squash bugs rolled in dust and placed on untreated leaves.
C. A concentrate consisting of equal parts by weight of active compound. A mixture of *Triton X-100* and xylene was emulsified in water and sprayed on leaves, upon which untreated adults were confined.
D. Same as C except both leaves and squash bugs sprayed with emulsion.

[1] Two tests consisting of 10 adults each were made for each dilution.
[2] A solution of 2 parts xylene and 1 part *Triton X-100* diluted 1-500 in water.

quired for total knockdown was used as an index of rate of action and loss in toxicity of the surface due presumably to volatility and/or absorption DDT and *1068* were applied at 200 mg. per square foot, but due to the low solubility of the sample of benzenehexachloride used which was only 40 per cent active gamma isomer, only 100 mg. of this isomer could be applied per sq. ft. without greatly increasing the amount of liquid applied. The results of a typical series of tests are given in table 5.

The results indicate that DDT is the most permanent toxic surface while benzenehexachloride is the least permanent, with *1068* intermediate. These results are in agreement with preliminary volatility measurements which show *1068* to be considerably more volatile than DDT. All three materials, however, appear to be effective at the dosages used for a period of about 4 months. It should be emphasized that the speed and duration of residual action of these materials are largely dependent on the type of surface to which the treatment is applied. DDT leaves a crystalline deposit which clings well to porous surfaces but rapidly flakes

**Table 5.—The residual toxicity of DDT, benzenehexachloride and *1068* to adult female *Anopheles quadrimaculatus*.**

| Age of Treatment | Time for 100 Per Cent Knockdown in Minutes | | |
|---|---|---|---|
| | *1068* 200 mg. Per sq. ft. | DDT 200 mg. Per sq. ft. | Benzene hexachloride 100 mg. Per sq. ft. |
| New | 40 | 86 | 14 |
| 1 week | 40 | 108 | 29 |
| 8 weeks | 90 | 130 | 27 |
| 12 weeks | 60 | 99 | 43 |
| 16 weeks | 117 | 95 | 140 |

**Table 6.—Toxicity of DDT, *1068*, and γ-benzenehexachloride to 4th instar larvae of *Anopheles quadrimaculatus*.**

| Material and Dilution | Number of Larvae | Number of Tests | Av. Per Cent Mortality | |
|---|---|---|---|---|
| | | | 24 hours | 48 hours |
| Acetone Suspensions | | | | |
| *1068*—0.1 p.p.m. | 50 | 2 | 100 | 100 |
| 0.01 p.p.m. | 100 | 4 | 29 | 58 |
| 0.001 p.p.m. | 50 | 2 | 0 | 8 |
| DDT—0.1 p.p.m. | 50 | 2 | 100 | 100 |
| 0.01 p.p.m. | 100 | 4 | 39 | 68 |
| 0.001 p.p.m. | 50 | 2 | 16 | 16 |
| γ-Benzenehexachloride—0.1 p.p.m. | 50 | 2 | 100 | 100 |
| 0.01 p.p.m. | 50 | 2 | 2 | 48 |
| 0.001 p.p.m. | 50 | 2 | 0 | 0 |
| Xylene Emulsions | | | | |
| *1068*—0.1 p.p.m. | 40 | 2 | 100 | 100 |
| 0.01 p.p.m. | 100 | 5 | 93 | 100 |
| 0.001 p.p.m. | 40 | 2 | 30 | 65 |
| DDT—0.1 p.p.m. | 40 | 2 | 90 | 100 |
| 0.01 p.p.m. | 100 | 5 | 60 | 90 |
| 0.001 p.p.m. | 40 | 2 | 25 | 50 |
| γ-Benzenehexachloride—0.1 p.p.m. | 40 | 2 | 100 | 100 |
| 0.01 p.p.m. | 40 | 2 | 30 | 62 |
| 0.001 p.p.m. | 40 | 2 | 8 | 23 |
| Dusts | | | | |
| *1068*—1 per cent—0.001 lb. per acre | 100 | 2 | 76 | 88 |
| 0.1 per cent—0.0001 lb. per acre | 100 | 2 | 14 | 47 |
| DDT—1 per cent—0.001 lb. per acre | 100 | 2 | 60 | 68 |
| 0.1 per cent—0.0001 lb. per acre | 100 | 2 | 12 | 36 |
| γ-Benzenehexachloride— | | | | |
| 1 per cent—0.001 lb. per acre | 100 | 2 | 99 | 100 |
| 0.1 per cent—0.0001 lb. per acre | 100 | 2 | 19 | 48 |

off smooth hard surfaces, while *1068* leaves a liquid deposit which clings very well to smooth hard surfaces but may be absorbed by porous materials.

Two minutes contact with a *1068*-treatment at 200 mg. per square foot one week old repeatedly gave 100 per cent mortality of female *Anopheles quadrimaculatus* in 24 hours; while 5 minutes contact with a 200 mg. per square foot DDT surface of the same age gave mortalities ranging from 20 to 55 per cent in 24 hours. Thus it appears that this insect will pick up a lethal dose of *1068* upon much briefer contact than is necessary with DDT.

LARVICIDAL TESTS ON THE ANOPHELINE MOSQUITO *Anopheles quadrimaculatus*.—Tests were made of acetone suspensions of DDT, γ-benzenehexachloride, and *1068* in distilled water. The materials were added in acetone solution by pipette to distilled water in a one liter volumetric flask and thoroughly shaken before pouring into a pan containing fourth instar *A. quadrimaculatus* larvae. Similar larvicidal tests were also made on emulsified xylene solutions of these compounds. These were made from a solution containing 25 per cent active agent, 7 per cent *Triton X-100* emulsifier and 68 per cent xylene. Another series of tests were made on dusts prepared from the active compounds. The DDT and γ-benzenehexachloride dusts were prepared by grinding the materials with talc as a diluent. The *1068* dust was prepared by impregnating the talc with an acetone solution of the active ingredient. The dusts were allowed to settle from a dusting tower onto the water surface of pans containing the larvae. In all these tests, the larvae were not considered dead if they showed any movement when touched.

As seen from the results shown in table 6 there appear to be no significant differences in the relative toxicities of the three materials to *Anopheles quadrimaculatus* larvae regardless of the manner in which they were formulated and applied.

PEET-GRADY TESTS.—The toxicity of the two compounds DDT and *1068* were compared on the adult housefly by the "large group" Peet-Grady test procedure (Soap Blue Book 1944). Each compound has a toxicity to the housefly greater than that of the pyrethrins, but they are notably different in that they produce paralysis at a much slower rate when used at concentrations near or below their minimum lethal dosage. In order to use the Peet-Grady method for comparative toxicity studies, it was necessary to apply the compounds in solution with an agent which would produce a high percentage paralysis within the prescribed 10-minute exposure period and yet not add appreciably to the toxicity of the compounds. It was found that the addition of 1.0 per cent by volume of *Lethane 384 Special* to a deodorized kerosene solution containing DDT or *1068* would accomplish this purpose.

The results of the Peet-Grady tests are recorded in table 7 where it is shown that concentrations of the compounds required to produce mortalities of approximately 95 per cent are 0.2 per cent for DDT and 0.05 per cent for *1068*. The LD 50 determined for the two compounds by plotting a dosage mortality curve by the Bliss (1938) method of probits shows that a concentration of approximately .06 per cent is required for DDT as compared with a concentration of .02 per cent for *1068*.

**Table 7.—Comparative toxicity of *1068* and DDT to houseflies as measured by the Peet-Grady test procedure.[1]**

| Compound | Per Cent Conc. Wt./Vol. | Av. No. Flies Per Test | Av. Per Cent Mortality 24 Hours | | Peet-Grady Rating |
|---|---|---|---|---|---|
| | | | Compound | O.T.I. | |
| *1068* | 0.1 | 476 | 99.6 | 43.9 | +56.1 |
| *1068* | 0.05 | 459 | 96.2 | 40.5 | +55.7 |
| *1068* | 0.025 | 517 | 60.9 | 45.0 | +15.5 |
| *1068* | 0.015 | 488 | 48.0 | 44.0 | + 4 |
| DDT | 0.2 | 482 | 95.4 | 47.5 | +47.9 |
| DDT | 0.1 | 473 | 67.2 | 44.5 | +22.7 |
| DDT | 0.05 | 451 | 39.0 | 47.3 | − 8.3 |
| Control[2] | | 521 | 6.0 | 44.6 | |

[1] Six tests were made at each concentration except *1068* at 0.015 per cent where three tests were made.

[2] *Lethane 384 Special* one per cent solution in deodorized kerosene.

TOXICITY OF *1068* AND DDT TO THE AMERICAN ROACH, *Periplaneta americana*.—The foregoing results show that lower concentrations of *1068* than DDT, applied in the form of dust or spray, are required to produce a given percentage mortality in most of the insects studied. This leads to the assumption that the individual fatal dose is also lower for *1068*. In order to test the reliability of this assumption more precise toxicity data were obtained by applying measured dosages of the two compounds to the

thoracic tergites of adult American roaches.

The active compounds were formulated into easily emulsifiable solutions by adding 10 ml. of *Triton X-100* to 90 ml. of xylene containing 25 grams of active compound. These solutions were then emulsified in the volume of water required to obtain the desired amount of toxicant in 10 cubic millimeters, which is the quantity of emulsion applied to the roaches. The application was accomplished by using a blunted No. 27 hypodermic needle on a .25 ml. tuberculin syringe. The syringe was mounted on a block of wood so that its plunger could be driven by the screw on a micrometer caliper also mounted on the wood block in a manner similar to that described by Trevan (1922). By using this procedure the error in application was found to be not greater than 5 per cent. The results of these experiments are shown in table 8.

Table 8.—Toxicity of *1068* and DDT to the American roach, *Periplaneta americana*.

| Compound | Micrograms Per Gram Roach | Number Roaches | Percentage Mortality | | | | |
|---|---|---|---|---|---|---|---|
| | | | 24 Hrs. | 48 Hrs. | 72 Hrs. | 96 Hrs. | 120 Hrs. |
| DDT | 50 | 20 | 0 | 15 | 30 | 40 | 75 |
| DDT | 33 | 30 | 0 | 0 | 20 | 30 | 43 |
| DDT | 25 | 10 | 0 | 10 | 30 | 30 | 30 |
| *1068* | 50 | 5 | 0 | 20 | 60 | 100 | 100 |
| *1068* | 25 | 25 | 4 | 36 | 56 | 76 | 96 |
| *1068* | 16.6 | 30 | 0 | 3 | 27 | 47 | 66 |
| *1068* | 12.5 | 20 | 0 | 0 | 30 | 40 | 45 |

Straight line dosage mortality curves obtained by plotting log dosages against mortality probits show that *1068* is probably 3 times as toxic as DDT to this insect when applied in this manner. The amount of DDT required to kill 50 per cent of American roaches in 120 hours is approximately 38 micrograms per gram of body weight as compared to 14 micrograms of *1068*. The amount of DDT required to kill 95 per cent in 120 hours is approximately 70 micrograms of DDT or 25 micrograms of *1068* per gram of body weight.

Tests as Stomach Poisons to the Adult Differential Grasshopper, *Melanoplus differentialis*.—The materials were made up as 10 per cent weight to volume concentrates in a 9:1 mixture of xylene and *Atlas G1036* emulsifier. These concentrates were then emulsified with a 25 per cent solution of molasses in water to give emulsions containing 0.5, 1.0 and 2.0 per cent active material depending on the dosage desired. Measured drops of the emulsions were delivered from the one-quarter cc. tuberculin syringe previously described. These drops were placed on the mouthparts of the grasshoppers which were observed until the drops were completely ingested. Insects failing to ingest the drops were discarded. After treatment, the grasshoppers were placed in wire cages with food and water. Mortality counts were made at 24 and 48 hours. Those insects unable to stand or to move other than for feeble leg twitching were counted as dead. Ten grasshoppers were used at each dosage. The results are reported in table 9. The 48-hour mortality records were less reliable due to a mor-

Table 9.—Toxicity of DDT, *1068* and γ-benzenehexachloride as stomach poisons to *Melanoplus differentialis*.

| Material | Dosage in Micrograms | Per Cent Emulsion | Per Cent Mortality 24 Hours |
|---|---|---|---|
| DDT | 100 | 2 | 30 |
| | 50 | 1 | 20 |
| | 25 | 0.5 | 0 |
| | 10 | 0.5 | 0 |
| | 5 | 0.5 | 0 |
| *1068* | 50 | 1 | 70 |
| | 25 | 0.5 | 30 |
| | 10 | 0.5 | 10 |
| | 5 | 0.5 | 0 |
| γ-Benzene-hexachloride | 25 | 0.5 | 100 |
| | 10 | 0.5 | 40 |
| | 5 | 0.5 | 10 |
| | 2 | 0.5 | 0 |
| Control[1] | | | 0 |

[1] Grasshoppers given maximum amount of xylene-emulsifier-molasses emulsion used in tests.

tality in the check and are not included in the table, but generally showed no significant increase over the 24-hour values. From these data it is estimated that the median lethal dosage per gram of body weight for γ-benzenehexachloride lies between 5 and 10 micrograms, *1068* between 12.5 and 25 micrograms, and DDT greater than 50 micrograms. The average weight of the grasshoppers used in these tests was 2.0 grams.

SUMMARY.—A chlorinated hydrocarbon having the empirical formula $C_{10}H_6Cl_8$, referred to as *1068*, may be obtained as a viscous, colorless, odorless, compound which is soluble in all proportions in the common organic solvents including crude and highly refined petroleum oils. A more complete description of its chemical structure will be presented in the near future as soon as certain features are clarified. Meanwhile it seemed desirable to present the results of laboratory tests on several species of insects, because the compound appeared to have exceptional toxicity and promise of immediate use as an insecticide.

A series of parallel tests was made on *1068* and DDT applied as aqueous dispersions to the spiraea aphid and to the pea aphid. The results of these tests indicated that *1068* is several times more toxic to these insects than is DDT and that the pea aphid is the least susceptible of the two species to both compounds. Aqueous sprays of *1068* and DDT applied to potato foliage and later infested with third and fourth instar larvae of the Colorado potato beetle likewise showed *1068* to be more toxic than DDT to this insect. The two compounds applied to the adult squash bug in the form of aqueous sprays and as dusts revealed DDT to be relatively ineffective, as compared with *1068*.

The residual toxicity of *1068*, DDT, and γ-benzenehexachloride was compared by applying emulsified xylene solutions of the compounds to the surface of wallboards, which were then exposed at intervals over a period of 16 weeks to adult *Anopheles quadrimaculatus*. The increase in time required to produce a 100 per cent knockdown as the treated surfaces aged was used as an index of loss in effectiveness of the compounds, by volatilization, absorption or other means. After 16 weeks of aging, the time required for γ-benzenehexachloride treatment to produce a 100 per cent knockdown had increased by a factor of 10 over its initial knockdown time. In the same period the time required for the *1068* treatment to produce a 100 per cent knockdown had increased by a factor of 3, whereas, that of DDT remained approximately constant. It would seem that of the three materials DDT will provide the most permanent toxic surface. It is believed that the loss in residue effect from *1068* and γ-benzenehexachloride is due to their greater volatility, the latter being the more volatile of the two. Preliminary volatility measurements indicate *1068* to be considerably more volatile than DDT.

A series of tests made to compare the larvicidal properties of *1068*, DDT and γ-benzenehexachloride to the larvae *Anopheles quadrimaculatus* resulted in the conclusion that there was no significant difference in the three compounds when applied as acetone suspensions, emulsions and dusts.

The relative toxicity of *1068* and DDT to the adult housefly was measured by the "large group" Peet-Grady procedure. Under the conditions of the tests it was found that 0.2 per cent DDT or 0.05 per cent solutions of *1068* are required to produce a 95 per cent mortality in 24 hours. A median lethal concentration was estimated from probit-log dosage curves which indicated that a 0.06 per cent solution of DDT or a 0.02 per cent solution of *1068* would be required.

The relative toxicity of *1068* and DDT to the American roach was determined by applying precisely measured dosages to the thoracic tergites. Dosage mortality curves plotted from data obtained in these tests showed *1068* to be approximately three times as toxic as DDT to this insect. The LD 50 for *1068* was found to be approximately 14 micrograms per gram of body weight as compared to 38 micrograms per gram of body weight for DDT, when measured 120 hours after treatment. The corresponding values for LD 95 were approximately 25 micrograms per gram of body weight for *1068* and 70 micrograms for DDT per gram of body weight.

Stomach poison tests with *1068*, DDT and γ-benzenehexachloride were made on the adult grasshopper *Melanoplus differentialis*. Emulsions of xylene solutions of the active compounds were fed to the

grasshoppers in measured drops. Twenty-four hour mortality records indicated the median lethal dosage for γ-benzenehexachloride to lie between 5 and 10 micrograms, for *1068* between 12.5 and 25 micrograms and for DDT to be greater than 50 micrograms per gram of body weight.

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# Preliminary Investigations on Heat-Generated Aerosols for the Control of Agricultural Pests

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Following the spectacular success of the aerosol bomb in the protection of the armed forces against disease-carrying insects, especially mosquitoes, attention was drawn to the possibility of using aerosols for the control of agricultural insect pests. The aerosol bomb utilizes gases such as *Freon* (dichlorodifluoromethane) or methyl chloride to produce the aerosol. However, gases of this type are too expensive for the generation of aerosol clouds intended to cover large areas. Consequently other means of generation were explored. The method of generating an aerosol does not influence its effectiveness, this being principally a function of particle size, provided the ultimate concentration of insecticide is the same.

The original method of creating aerosols by heat, as described by Sullivan *et al.* (1940) was deemed to be the most promising, and efforts were concentrated on the further development of this method. The aerosols so created are termed "heat-generated" to distinguish them from those generated by liquefied gas or other means. A number of persons have participated in the subsequent development.

HISTORY OF DEVELOPMENT.—Sullivan and co-workers produced their aerosols by spraying an oil solution of insecticide on a hot plate. In 1941, A. H. Yeomans built a modification of the hot-plate generator, in which the insecticide solution was sprayed by an electric atomizer onto the inner walls of a heated tube. On contact, the solution was volatilized, to be recondensed into a smoke aerosol upon mixture with cooler air. The tube was heated from a surrounding block of steel in which electric heaters were embedded. Yeoman's attempts at a gasoline-heated generator of the same general type were taken over, upon his entrance into the military service, by the writer and C. S. Wilson. A portable gasoline-heated generator was built and was demonstrated in August 1943 to the staff of the Orlando, Florida, laboratory of the Bureau of Entomology and Plant Quarantine, engaged in studying the control of insects affecting the armed forces. From this demonstration came the suggestion that army screening-smoke generators might be utilized for production of aerosols in quantities needed for large-area treatment.

Accordingly, a screening-smoke generator was obtained on loan from Division 10, National Defense Research Committee (NDRC), the research group largely responsible for the development of the oil-fog type of generators for military uses. Tests in November 1943 against natural populations of mosquito adults and larvae in large-area application looked promising. In these tests DDT was dissolved in the oil used to produce the screening smoke.

[1] Reference is made in this article to joint studies conducted under Office of Scientific Research and Development contracts, and that organization in approving publication, does not vouch for the accuracy of the statements made.

The groups under contract to Division 10, NDRC, as a part of their studies, had done intensive research on methods of collecting and measuring the size of particles in screening smokes, and had assembled much information on this point, which was made available to the Bureau. Cooperation was also arranged with the Columbia University Central Aerosol Laboratory of Division 10, directed by V. K. LaMer, for studies of the optimum range of particle sizes for insecticidal purposes. It was expected that this would be different from the optimum range for purposes of obscuring vision. During January 1944, in tests with homogeneous aerosols generated in a LaMer-Sinclair laboratory generator already perfected in screening-smoke studies, it was established that particles larger than those in screening smokes were more effective in killing insects.

Efforts were then concentrated on the modification of existing types of screening-smoke generators so as to produce larger particles. The Columbia University group undertook the problem of designing a new generator for the production of insecticidal aerosols.

At this time a team was formed by several divisions within the Bureau of Entomology and Plant Quarantine, consisting of S. F. Potts, T. E. Bronson, F. A. Poos and the writer, to study further the possibilities of aerosols for large-area control of agricultural pests. The findings of the groups working on military aerosols were made available to this team. Pending the development of a generator at the Columbia University laboratory, attempts were made to modify other types.

A multiple hot-tube generator was built, but the particle-size range was not satisfactory, and the idea was abandoned. Modified "smoke-pots" were also tested, and these likewise produced aerosols with two small particles. The army screening-smoke generator used in the Florida tests was modified so as to produce aerosols with an average particle size of approximately 2 to 3 microns in diameter, by permitting additional coagulation of the condensing particles as suggested by Whytlaw-Gray (1936), and Stumpf & Jander (1936).

Tests made with this modified generator against the pea aphid (*Macrosiphum pisi* (Kltb.) ) on alfalfa gave control only 25 to 50 feet from the generator, which was not promising considering the amount of DDT used. On the other hand, in trials against the gypsy moth (*Porthetria dispar* L.) in forest areas on Cape Cod, larvae were affected 1400 feet away from the point of generation, and good control was obtained on areas up to one-half acre, from aerosols produced from a single point and drifted downwind.

During the past year the Hochberg-LaMer generator designed at the Columbia University laboratory has been perfected and tested. It can be adjusted to produce almost any desired particle size and causes no destruction of DDT due to the heat used. Its principle is different from that of the screening-smoke generators, and the maximum temperature is only about half as high.

Recently an inventor's model of this generator was made available to the Bureau by the Columbia University laboratory and was used in further tests against the gypsy moth, with very encouraging results, which will be reported later. In the meantime the Bureau has been participating in cooperative research under funds supplied by the Office of Scientific Research and Development wherein the influence of speed of motion, rate of deposit, and particle size have been critically studied under controlled conditions. In these tests the Columbia University laboratory was responsible for all physical and chemical aspects, and the Bureau laboratory for all biological phases. All this information will be made generally available after security restrictions have been removed, but until then it will serve as a background in the further study of the application of aerosols to the control of agricultural pests.

METHOD OF USE.—The present method of applying heat-generated aerosols is to mount a generator on a truck and move slowly across the direction of the wind, so that the aerosol will drift over the area to be treated from a front approximately at right angles to the wind drift. It is possible to treat up to several hundred acres in part of a day, at a rate of 30 seconds to 3 minutes per acre depending on the size of generator and dosage desired. With the present generators aerosols can be produced which contain up to 16 per cent or more of DDT in the original mixture, at intake rates of 20 to 100 gal-

lons per hour per generator. Oils ranging from low to high solvent action for DDT or other insecticides can be used, either straight or with the addition of a mutual solvent. The differences in their effectiveness against insects, and their possible effect on plant foliage, are yet to be explored.

The concentration of aerosol, and therefore the effectiveness, is greatest nearest the generator, and diminishes with the distance. In order to get a high degree of control at a given distance from the path of the generator, it is necessary to overdose the intervening area. For this reason it is more economical to treat in narrow strips than in deep areas.

Aerosols are considered to be of greatest value when the insect concerned can be directly contacted by the particles. A certain amount is deposited on leaves, bark, etc., which can act as an effective residue, but since the amount is dependent upon many factors, it could vary widely between extremes. Tests with gypsy moth larvae indicated a lack of feeding on foliage previously exposed to a DDT aerosol, over a period of many days. Even though the application had been light, this condition was to be observed in a strip about 100 feet or more in width.

Application is dependent upon favorable atmospheric conditions to drift the aerosol over the area desired and have it well distributed to all points where the insects occur. For open terrain and low-growing crops inversion conditions—that is, a layer of cool air next to the ground—with a wind drift or a light breeze of 1 to 2 miles per hour, are ideal. Usually the relatively calm period at daybreak or sundown is suitable. During the daytime, especially on sunny days, turbulent conditions necessitate a steady wind of 5 miles per hour or greater, to hold the aerosol to the ground for low-growing vegetation.

On the other hand, for use in forests considerable wind is necessary above the trees to provide any movement below the canopy. Successful tests have been applied in forests with top winds of 25 miles per hour or greater. Within the forest such winds produce turbulence, which tends to distribute an aerosol to all heights, and yet maintain a general direction of movement. Rising aerosol clouds are immediately driven back down into the canopy by the increased air movement above the canopy. Light winds above forest areas do not maintain movement in one direction within the canopy; consequently very unfavorable turbulence results. Air drainage down slopes at dusk is a very desirable condition. Air turbulence along roadways in forest areas was overcome by use of a powerful blower to start the aerosol cloud through the forest where, once away from the local turbulence, movement in one direction was positive.

If an aerosol induces flight or other motion of the insects being treated, it is reasonable to expect an increased effect, since a larger number of particles should come in contact with them. In some instances DDT aerosol have induced flight of adults or activity of larvae. This effect could also be obtained by the addition of an irritant, possibly pyrethrum.

It is not considered that aerosols will become a general substitute for sprays or dusts. Rather it is anticipated that they will prove to be an effective means of control in specific insect problems where present methods are handicapped for one reason or another.—10-17-45.

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Baby-bye here's a fly,
Let us watch him, you and I.
How he crawls, up the walls—
Till DDT gets him and he falls.

# Insect-Repellent Properties of 2-Ethylhexanediol-1,3

PHILIP GRANETT and HARRY L. HAYNES, *Rutgers University*[1]

Under the stimulus of war needs, activity in the development of insect repellents to protect people from the bites of Arthropod disease vectors was greatly intensified. The combined efforts of industry, Government agencies, and institutional laboratories resulted in advancing the effectiveness of repellents far beyond what had been available before the war. One of the chemicals developed for personal use by such efforts is 2-ethylhexanediol-1,3 known during the war as *Insect Repellent No. 612*,[2] the test number assigned to it at Rutgers University.

Under a research Fellowship at Rutgers University sponsored by the National Carbon Company, repellent research was conducted on a number of chemicals among which was 2-ethylhexanediol-1,3 synthesized by Dr. B. G. Wilkes.[3] After initial entomological screening tests the best of these were passed on to the cooperating Government agencies for further laboratory and field trials. Ethylhexanediol was outstanding among these chemicals because it combined a high order of effectiveness as a repellent with a high safety factor as regards toxicological action on users and in addition possessed acceptable accessory properties.

It is the purpose of this paper to present some of the results of the experimental studies and describe the properties of this chemical.

PHYSICAL AND CHEMICAL PROPERTIES.—Ethylhexanediol is a slightly viscuous, colorless liquid having a mild odor somewhat like witch-hazel. It is stable under extremes of storage conditions and unlike many other recognized repellents, its solvent action in contact with various surfaces is relatively weak. It will not affect clothing or dissolve cellulose acetate, cellulose nitrate, polystyrene, *Vinylite* resin *VYNS*, *Lucite* or *Plaskon*. It has a slight softening effect on spar varnish, containing resin such as dammar. It rapidly softens shellac.

Other physical and chemical properties of ethylhexanediol are listed below.

| | |
|---|---|
| Molecular Weight | 146.22 |
| Specific Gravity at 20/20°C. | 0.9422 |
| Vapor Pressure at 20°C. mm. Hg. | 0.01 |
| Refractive Index at 20°C. nD. | 1.4511 |
| Boiling Point at 760 mm. Hg°C. | 244 |
| Freezing Point °C. | Below −40 |
| Solubility in water at 20°C. (per cent) | 4.2 |
| Solubility water in, at 20°C. (per cent) | 11.7 |
| Viscosity at 20°C. centipoises | 323 |
| Flash point °F. | 260 |
| Average weight per gal. at 20°C. lb. | 7.84 |

*Specifications* for the commercial material are:

| | |
|---|---|
| Maximum acidity, per cent as acetic | 0.01 |
| Specific gravity 20/20°C. | 0.9390 to 0.9430 |
| Boiling range °C. | 240 to 250 |
| Maximum color, A.P.H.A. Units | 50 |

REPELLENT PROPERTIES.—It should be emphasized that in the evaluation of repellency, a statement of the protection time afforded by a chemical means relatively little unless the conditions under which it was used are definitely stated. Even then all the effects of environmental and biological factors cannot be established; a slight change in conditions of use may cause a great change in the protection time. It is advisable, wherever possible, to indicate the effectiveness of a known material used under the same conditions. In this way the comparative merit of a substance can be established in addition to the actual time figures.

In the following attempt to indicate the repellent properties of ethylhexanediol, we have chosen dimethyl phthalate for a comparison material. Mixtures containing these two ingredients and other materials have been found effective but because detailed data is not as available as for the chemicals alone, comparisons with them are not included here.

PROTECTION AGAINST MOSQUITOES.—Because of the great need to protect troops against diseases carried by mosquitoes, the bulk of the information on ethylhexanediol was obtained against those species of disease vector. In general, the repellent was found to be highly effective against most *Aëdes* species of mosquitoes and somewhat variable against *Anopheles* species.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.
[2] Now being sold under the trade mark Insect Repellent "6-12" by the Carbide and Carbon Chemicals Corporation.
[3] Senior Fellow, Organic Synthesis Fellowship, Mellon Institute of Industrial Research.

The tests were carried out by applying measured quantities of chemical, usually 1 cc. to about 100 square inches of skin and exposing the treated surface to hungry mosquitoes. The time from application to first definite bite was selected as the protection time.

Under our (Rutgers) laboratory conditions (Granett & Haynes 1944) (75° F., 50–60% relative humidity) ethylhexanediol was repellent against *Aëdes aegypti* for about 9 hours. Dimethyl phthalate under these conditions was repellent for about 7 to 8 hours. It was observed, however, that lighting and probing on treated surfaces began much sooner with dimethyl phthalate.

Against *Anopheles quadrimaculatus* ethylhexanediol was repellent for about one hour as compared with about two hours for dimethyl phthalate.

In the field against salt marsh mosquitoes, mainly *Aëdes sollicitans* and *Aëdes cantator* under vigorous biting conditions (4 to 30 bites per minute on untreated areas) protection from ethylhexanediol was about six hours as compared to about 4 hours for dimethyl phthalate.

Travis & Jones (1944) report 5 to 6 hours protection against *Aëdes* species in the laboratory and the field as compared with about 3 to 4 hours protection for dimethyl phthalate. Against *Anopheles quadrimaculatus* however, the picture is reversed showing only a little over an hour for the ethylhexanediol as compared to about 3.5 hours for dimethyl phthalate.

Comparatively little experimental data is available for trials with repellents in tropical areas. Gorgas Memorial Laboratory tests[1] against *Anopheles albimanus* in the Panama region, indicate that ethylhexanediol is effective for 3 to 4 hours as compared to 1½ to 2 hours for dimethyl phthalate. Recent reports[1] from the South Pacific indicate that ethylhexanediol is very good against *Anopheles punctulatus farauti*, lasting about 6 hours as against less than an hour for dimethyl phthalate. This information is particularly significant as it indicates the considerable degree of protection obtained with ethylhexanediol against malarial carriers in regions where the troops were most in need of protection. The data cited above is listed in the accompanying table 1.

Table 1.—Repellent tests against various species of mosquitoes 1942 to 1945.

| Location of Test | Test Species | 2-Ethylhexanediol-1,3 | | Dimethyl Phthalate | |
|---|---|---|---|---|---|
| | | No. of Tests | Protection Time | No. of Tests | Protection Time |
| | | | *Minutes* | | *Minutes* |
| Rutgers Laboratory | *Aëdes aegypti* | 60 | 536 | 29 | 455 |
| | *Anopheles quadrimaculatus* | 4 | 60 | 5 | 123 |
| New Jersey Salt Marshes | *Aëdes sollicitans* and *Aëdes cantator* | 19 | 352 | 6 | 233 |
| Reported in U. S. Patent No. 2,356,801 Travis & Jones, Aug. 29, 1944 | *Aëdes aegypti* | | 363 | | 234 |
| | *Anopheles quadrimaculatus* | | 78 | | 206 |
| | *Aëdes taeniorhynchus* | | 276 | | 153 |
| Tests in Panama Kumm & Jobbins | *Anopheles albimanus* | 40 | 157 | | 103 |
| | | | 230 | | 90 |
| Tests in South Pacific Travis | *Anopheles punctulatus farauti* | | 350 | | 40 |

These trials were all made on restricted areas of the body, arms or legs, and with uniform application of 1 cc. to about 100 square inches of skin surface.

Effect of Varying Amount.—Varying the amount applied either by use of diluents or by increasing or decreasing the actual quantities tends to increase or decrease repellency. In the case of diluents the repellency is usually a function of the concentration of the active ingredient contained in the mixture.

An indication of what may be expected by varying the quantity applied is shown in the following tabulation which lists the

[1] Personal communications.

results of trials in the laboratory against captive mosquitoes, *Aëdes aegypti*, following the application of 0.3, 0.5, 1.0 and 2 cc. of ethylhexanediol to approximately 100 square inches of skin surface. The protection times of this special series of tests were uniformly high as compared with the average obtained over a long period in the laboratory.

**Table 2.—Repellent trials with varying applications of ethylhexanediol against captive mosquitoes, Aëdes aeygpti, in the laboratory.**

| Amount Applied | No. Tests | Average Protection Time | Ratios of Amounts Applied | Ratios of Protection Time Obtained |
|---|---|---|---|---|
| *cc.* | | *Minutes* | *cc:cc* | *Min:Min* |
| 0.3 | 5 | 288 | | |
| 0.5 | 10 | 404 | 0.5:0.3=1.6 | 404:288=1.4 |
| 1.0 | 7 | 770 | 1.0:0.3=3.3 | 770:288=2.6 |
| | | | or | |
| | | | 1.0:0.5=2.0 | 770:404=1.9 |
| 2.0 | 2 | 1215 | 2.0:0.3=6.66 | 1215:288=4.2 |
| | | | or | |
| | | | 2.0:0.5=4.0 | 1215:404=3.0 |
| | | | or | |
| | | | 2.0:1.0=2.0 | 1215:770=1.5 |

A definite increase in repellency is observed as more repellent is applied although effectiveness is not directly proportional to the quantity used. When 1.0 cc. is applied instead of 0.5 cc., a 1.9 increase in repellency was obtained instead of doubling the protection. This fell off to 1.5 times increase when the 1 cc. application was doubled again. Two cc. per 100 square inches appears to be about the maximum amount which can be applied with this chemical before run-off occurs. A limited experiment along similar lines conducted with dimethyl phthalate indicated that protection time against *Aëdes aegypti* was:

| *Amount Used* | *Protection Time* |
|---|---|
| 0.5 cc. | 330 minutes |
| 1.0 cc. | 690 minutes |
| 2.0 cc. | 720 minutes |

The sharp falling off for the large amount is probably attributable in part to the fact that dimethyl phthalate is a much less viscous substance and it is almost impossible to retain the 2 cc. amount on the area used.

PRACTICAL USE TRIALS.—As has been stated, the figures cited are for experimental trials on small areas of skin. Under practical conditions of use, where protection is sought for all exposed surfaces, protection time is usually shorter. Our experience has been that in the field against salt marsh mosquitoes, *Aëdes sollicitans*, ethylhexanediol gave protection for from 2.5 to 4.5 hours while dimethyl phthalate protected for 2 to 2.5 hours. Numerous factors such as variation in perspiration, greater possibility of friction causing removal of repellent, variation in absorption by the skin in different areas, and the difficulty of providing uniform coverage, especially on head and face, may contribute to the difference in the protection observed.

These experiments served especially to show the need for thoroughly covering all areas to be protected. Protection is obtained only where the repellent is applied. Profuse perspiration was also found to be an important factor tending to reduce protection time. On the other hand, mild perspiration had little effect.

APPLICATION TO CLOTHES.—It has been estimated that about forty per cent of the bites received when exposed to mosquito attack in the field, may occur through clothes where they contact the body. An obvious way of preventing this is to treat the clothes with repellents. Preliminary trials (Granett & Haynes 1945) in the laboratory indicated that cotton cloth retains chemicals such as ethylhexanediol and dimethyl phthalate for long periods of time, presumably because of the low order of volatility of these chemicals. Recent trials of slack suits treated with approximately 20 per cent by weight of the repellents have been found to prevent biting of *Aëdes sollicitans* in the field up to 8 days when treated with ethylhexanediol and for about two days when treated with dimethyl phthalate. These suits were worn during approximately half of each working day. Suits stored in the laboratory and worn only to conduct a test (about one hour) retained repellency for 6 weeks in the case of ethylhexanediol and for 4 weeks in the case of dimethyl phthalate. Rain tends to wash the repellents from the cloth with consequent reduction in effectiveness.

ARTHROPOD PESTS OTHER THAN MOSQUITOES.—Table 3 indicates the protection time which is likely to be obtained from ethylhexanediol against a number of biting pests other than mosquitoes. Comparison has been made with dimethyl phthalate tried under similar conditions. The protection obtained is, for the most part somewhat similar to that obtained against various species of mosquitoes. In

the case of chiggers, where the material is applied to cloth, the repellents are remarkably effective, the treated cloth being repellent for days instead of hours.

In addition to results shown against stable fly, black fly, sand flies, fleas, and chiggers, the Orlando laboratory of the Bureau of Entomology and Plant Quarantine found[1] that ethylhexanediol while not completely effective, can provide protection against bedbugs, *Cimex lectularius*. Against the southern buffalo gnat, *Eusimulium pecuarum*, tests have been reported of 508 minutes average protection when ethylhexanediol was applied to 5 men and an average of 330 minutes on domestic animals.

**Table 3.—Repellent tests against arthropod pests other than mosquitoes.**

| Test Species | Ethyl Hexanediol | | Dimethyl Phthalate | |
|---|---|---|---|---|
| | No. of Tests | Protection Time | No. of Tests | Protection Time |
| | | *Min.* | | *Min.* |
| Stable fly (6)[1] | | | | |
| *Stomoxys calcitrans* | | 101 | | 47 |
| Black fly | | | | |
| *Simulium* spp. | 6 | 350 | | 316 |
| Sand flies | | | | |
| *Phlebotomus* spp. | | 240 | | 240 |
| Fleas (5) | | | | |
| *Ctenocephalides canis* | | | | |
| *C. felis* | 32 | 130 | 28 | 260 |
| Chiggers (4) | | On treated suits | | |
| *Eutrombicula* spp. | | | | |
| *Acariscus maroni* | | 30± days | | 30± days |

[1] Number in parenthesis indicates References cited.

Toxicological Properties.—An important factor to be considered for any material which is to be applied to the skin is its toxicological properties. Prior to large scale use of ethylhexanediol, toxicological studies were made at Mellon Institute under the direction of Dr. Henry F. Smyth, Jr. and by various Government agencies acting for the Surgeon General's Office. These studies were continued after the initial work showed it to be safe. Draize *et al.* (1944) published their procedures for the toxicological studies carried on at the Division of Pharmacology, U. S. Food and Drug Administration. These consisted of experiments to determine the dose for acute toxicity (oral and skin) on such animals as rabbit, guinea-pig and dog, subacute or twenty-day experiments, and for chronic toxicity trials in which daily doses are applied for a period of ninety days. Information on the rate of penetration and irritant effects is obtained from these experiments. Other experiments included determination of irritation by means of patch tests on animal and human skin, irritation as observed on animal mucous membrane, and sensitization as observed on animals.

For 2-ethylhexanediol-1,3 Draize (1944) reported for rabbits:

| | LD50 *mg./kgm.* |
|---|---|
| Oral (acute) | 2.6 |
| Skin (acute) | 10.0 |
| Skin 90 day inunction | 2.0 |

Limited experimental work has shown that certain individuals may develop a temporary feeling of heat or coolness at point of application. These symptoms soon disappear. In actual use it is also necessary to avoid applying the repellent to sensitive areas such as eyes or mouth.

In a summary compiled by the Office of Scientific Research and Development[1] the following statement was made, "The absorption (of ethylhexanediol) is very poor and evidently only small doses get through as indicated by the fact that very small doses intravenously cause death. It is irritating to the skin of all animals but has not been found irritating to man. The fact that it is poorly absorbed and is non-irritating to man and is very highly effective as a repellent leads to the conclusion that it is acceptable under the recommended condition of use." The irritation observed in animals obviously refers only to those animals actually worked with. The lack of irritation to man is further borne out by verbal reports from the Surgeon General's Office, the Pharmacological Division of the Food and Drug Administration, the National Institute of Health, U. S. Public Health Service and the U. S. Department of Agriculture, Division of Insects Affecting Man and Animals who have stated that they have no records showing skin irritation or sensitization from the use of ethylhexanediol in experimental or practical use by the armed forces. This is of especial interest as these groups are the official agencies for the receipt of such data and have some reports of irritation from the use of certain other repellents.

Conclusions.—Extensive repellent trials under laboratory and field conditions have shown 2-ethylhexanediol-1,3 to possess highly effective repellent properties against a variety of Arthropod pests.

[1] Personal communication.

Equally extensive toxicological studies and large scale use by the military forces have indicated its safety and lack of irritant properties.

Finally its physical and chemical properties are such as to make it easy and pleasant to apply and stable in storage or use.

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# Disodium Ethylene Bisdithiocarbamate for Control of Mexican Bean Beetle[1]

D. O. WOLFENBARGER and J. W. HEUBERGER,[2] *Delaware Agricultural Experiment Station, Newark*

In a recent popular article, Anon. (1944), it was reported that an organic chemical, disodium ethylene bisdithiocarbamate, termed *Dithane*,[3] when applied to the soil surrounding bean plants, inhibited Mexican bean beetle infestation. The implication is that the plants took up the chemical through the roots and that it was distributed systemically to the stems and foliage where it controlled the Mexican bean beetle. The significance of this method of insect or plant disease control may be far-reaching, if it can be applied practically.

Very brief mention may be made of some recent publications on the subject of insect control through absorption of chemicals by the roots or stem. Selenium, a poisonous chemical element, was used successfully by Hurd-Karrer & Poos (1936) in laboratory studies, inhibiting infestation and killing the apple grain aphid, *Rhopalosiphum prunifoliae* (Fitch). Craighead & St. George (1938), gave an historical resumé of this method of insect control, and Whitten (1941) described internal applications of chemicals to kill elm trees and to prevent bark beetle attacks. Insect control by this method has been long considered and frequently attempted, but with little or no favorable results.

The use of disodium ethylene bisdithiocarbamate was considered first as a fungicide by Dimond, *et al.*, (1943); its use as an insecticide appears to be a very recent development. Application of this material to potatoes by Heuberger and Manns (1943) gave increased yields. It was not determined, however, whether it had any insecticidal action.

MATERIALS AND METHODS.—A field experiment was set up using *Dithane* and a combination of basic copper arsenate and nicotine[4] as test materials on bush dwarf lima and string beans, both being planted 1.5 inches deep on July 3. Each planting was designed to give four replicates of each treatment in a randomized block experiment. Each treatment replicate was a rod-long row, and the rows were spaced 42 inches apart, giving plots of 0.0947 acre in size.

*Dithane* soil treatments, at dosages of 25, 100, and 400 pounds per acre, were applied by each of the following three methods: *In-the-row.* Six days before the seeds were planted, furrows were made and *Dithane* powder was placed in the soil 3 inches deep, in bands 3 inches wide.

[1] Published with the approval of the Director of the Delaware Agricultural Experiment Station as Publication 195 and Scientific Article 121 by the Department of Entomology. Information obtained through Purnell Projects E 11 (2) and P 13.

[2] Assistant Entomologist and Associate Plant Pathologist, respectively.

[3] Supplied by Rohm & Haas Company, Philadelphia, Pennsylvania.

[4] Supplied by Sherwin Williams Co., Bound Brook, New Jersey. Reported constituents: Basic copper arsenate 23.0%; nicotine, expressed as alkaloid 2.0%; and inert ingredients 75.0%.

SIDE DRESSING.—Two weeks after the seeds were planted, small 2-inch deep furrows were made on each side of the rows at a distance of about 3 inches from the small bean plants. *Dithane* powder was then distributed equally in the furrows and the soil was levelled. *Watering.* Three weeks after the seeds were planted, water solutions of *Dithane* were applied to the rows of plants. No further chemical was applied to plants treated by the three foregoing methods.

Two spray treatments were used. *Dithane* was applied at the rate of 2 pounds per 100 gallons of water and 200 gallons (4 pounds of the chemical) per acre. Basic copper arsenate-nicotine sulphate, 4 pounds per 100 gallons of water and 200 gallons per acre, was applied as the comparative spray treatment. Three applications were made in each case, 26, 32, and 41 days after the seeds were planted, by means of a knapsack-type hand-sprayer.

Statistical methods generally followed by research workers were used in the reduction and analysis of the recorded data.

EXPERIMENTAL DATA.—Delayed emergence of plants and reduced stands of both lima and string beans resulted from the "in-the-row" method of application of *Dithane.* Estimations on the influence of the chemical on stand were made 18 days after the seeds were planted; these, combining data for lima and string beans, are shown in table 1.

Stunted plants and marginal yellowing of the foliage resulted from "in-the-row" treatments and from the "side-dressing" and the "watering" methods as well. All such symptoms were more pronounced on plants treated with the heavier dosages.

**Table 1.—Stands of bean plants in *Dithane* "in-the-row" treatments, by dosages.**

| DOSAGE, POUNDS PER ACRE | AVERAGE STAND | |
|---|---|---|
| | Observed | Calculated[1] |
| | Per Cent | |
| 25 | 62.8 | 64.9 |
| 100 | 34.8 | 30.8 |
| 400 | 7.5 | 8.3 |

[1] Calculation from log-probit transformations by regularly-used regression methods.

Mexican bean beetles were sparsely prevalent on the beans until near the middle of the season, when they became more abundant. Infestation counts were made of larvae, pupae, and adults per 5 feet of row in each treatment and replication. Average infestations for each treatment are given in table 2.

Wide differences are obvious between the beetle infestations in the case of the different treatments. The most striking responses are those affected by soil applications of *Dithane;* the extent, based on dosage and regardless of the application method, is shown in table 3.

**Table 2.—Average Mexican bean beetle populations and bean yields on experimental plots.**

| TREATMENT | LIMA BEANS | | STRING BEANS | |
|---|---|---|---|---|
| | Beetle infestation per 5-foot row | Yield, oz. per rod row | Beetle infestation per 5-foot row | Yield, oz. per rod row |
| *Dithane* | | | | |
| In row @ 25 lbs. per acre | 30.5 | 187.5 | 140.8 | 124.0 |
| @100 lbs. per acre | 8.0 | 174.0 | 12.5 | 112.3 |
| @400 lbs. per acre | 2.5 | 96.0 | 0.5 | 85.0 |
| Side dressing @ 25 lbs. per acre | 42.8 | 247.3 | 197.3 | 106.3 |
| @100 lbs. per acre | 11.8 | 274.5 | 32.5 | 88.5 |
| @400 lbs. per acre | 2.5 | 215.5 | 3.3 | 65.3 |
| Watering @ 25 lbs. per acre | 72.5 | 226.5 | 185.5 | 98.5 |
| @100 lbs. per acre | 19.0 | 201.5 | 38.3 | 92.0 |
| @400 lbs. per acre | 3.8 | 171.5 | 2.0 | 77.5 |
| Spray @2 lbs. per 100 gals. water | 16.8 | 202.5 | 32.8 | 124.5 |
| Basic copper arsenate-nicotine sulphate, 4 lbs. per 100 gals. water | 9.0 | 256.5 | 7.5 | 128.3 |
| Check, no treatment | 68.8 | 217.0 | 199.3 | 106.8 |
| Minimum difference for significance | 22.6 | 45.3 | 56.4 | 47.7 |

**Table 3.—Mexican bean beetle populations on beans treated with different dosages of *Dithane* applied to the soil.[1]**

| Dosage, Pounds per Acre | Average Number of Larvae, Pupae, and Adults per 5 Feet of Row | |
|---|---|---|
| | Lima Beans | String Beans |
| 25 | 49.4 | 174.5 |
| 100 | 12.9 | 42.2 |
| 400 | 2.6 | 2.2 |

[1] Exclusion of "in-the-row" method of application, by virtue of the reduced stands of plants, gives averages as follows:

| Dosage, pounds per acre | Beetle populations | |
|---|---|---|
| | Lima Beans | String Beans |
| 25 | 57.4 | 191.4 |
| 100 | 15.4 | 35.4 |
| 500 | 2.6 | 2.6 |

Dosage effects, studied graphically, were observed to become linear by the use of double logarithmic graphs. Logarithmic conversions of the data, suggested by Dr. F. M. Wadley (personal correspondence), were used to compute regressions of beetle infestations on *Dithane* dosage and are shown in figures 1 and 2.

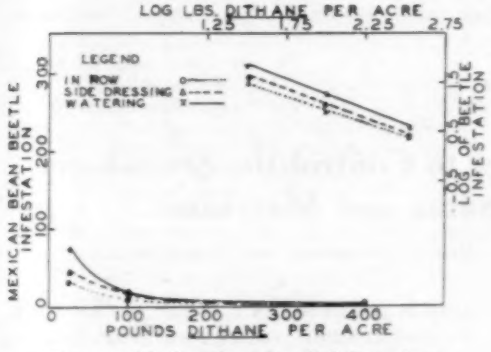


FIG. 1.—Mexican bean beetle infestations on *Dithane* treated lima beans.

Bean yield data, a total of all green pods harvested, are given as the average ounces for rod-rows (0.0947 acre), for each treatment, in table 2.

Marked differences in yield are observed, the most striking of which were previously mentioned in connection with beetle infestations as dosage responses. Average yields for the different dosages, for both lima and string beans, are shown in table 4.

A graphic illustration of the effect of dosage on yield is presented in figure 3, in which the yields from the different application methods are plotted against dosages.

DISCUSSION OF RESULTS.—Reduction of Mexican bean beetle infestations fol-

**Table 4.—Yields from bean plants treated with different dosages of *Dithane* applied the to soil.**

| Dosage, Pounds per Acre | Average Ounces of Beans per Rod Row | |
|---|---|---|
| | Lima Beans | String Beans |
| 25 | 220.4 | 109.6 |
| 100 | 216.7 | 97.6 |
| 400 | 161.1 | 75.9 |

lowed soil or spray treatments of *Dithane*, indicating that this compound has value as an insecticide. Whether its action is toxic, repellent, or otherwise is not known. Reduced beetle infestations, interpreted as dosage responses, were most marked between the 25 and 100 pound-per-acre

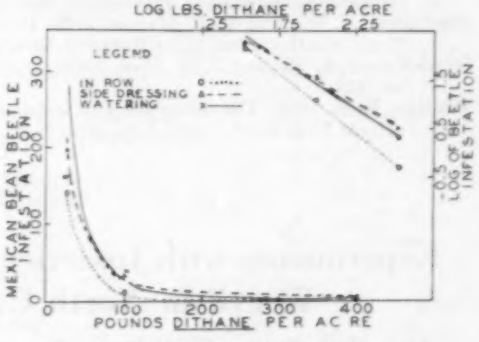


FIG. 2.—Mexican bean beetle infestations on *Dithane* treated string beans.

treatments. Both spray treatments, however, were practically no different from the 100 pound-per-acre soil treatment. Similar trends in beetle populations are noted where *Dithane* applications were made to the plants by means of treatments applied to the soil.

Yields of beans were altered considerably by the *Dithane* treatments. Although the 25 pound-per-acre treatments provided slightly greater yields than untreated plants, the 400 pound-per-acre treatments reduced the yields.

The beans were lightly populated with the potato leafhopper, *Empoasca fabae* (Harr.), and an occasional cotton square borer, *Strymon melinus* Hbn., was observed infesting bean pods. No indication

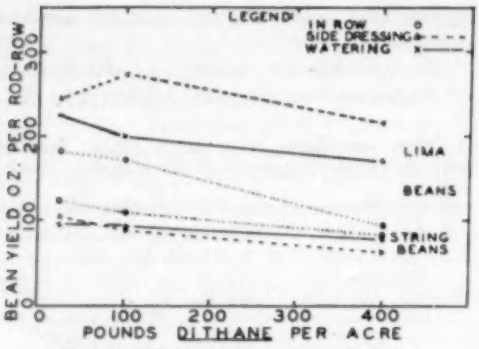


FIG. 3.—Yields of beans from *Dithane* treated lima and string beans

of control in the case of these insects was noted for any treatment. Disease was absent in these plantings. Beans were frequently tasted to note any changes which might be attributed to the *Dithane* treatments. Never was there any suggestion of an impaired flavor of the treated beans which could be associated with this material.

SUMMARY AND CONCLUSIONS.—Disodium ethylene bisdithiocarbamate (*Dithane*) applied to the soil around bean plants and as a foliage spray was found to control the Mexican bean beetle. Dosages of 100 and 400 pounds applied as soil treatments effectively reduced beetle infestations, but reduced the yields as well. Further work should be performed, therefore, before *Dithane* can be recommended for Mexican bean beetle control. —11-9-45.

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# Experiments with Insecticides to Control the Strawberry Weevil in North Carolina and Maryland

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Although the strawberry weevil, *Anthonomus signatus* Say, has been an important pest of strawberries for many years, no very satisfactory method of controlling it has been developed, and very little has been published on the value of insecticides for this purpose. Headlee (1918) and Baerg (1923) reviewed the literature on control and conducted insecticidal experiments. Headlee (1918) demonstrated that in fields severely infested with the strawberry weevil the injury could be checked and the yields materially increased by making two applications of a mixture of 1 part of lead arsenate and 5 parts of sulfur at 40 to 67 pounds per acre. As a result of this work the lead arsenate-sulfur treatment became widely used. Headlee also demonstrated that pyrethrum, tobacco dust, soap, and bordeaux mixture were relatively ineffective. In experiments by Baerg (1923) calcium arsenate was as effective as lead arsenate, and as a diluent hydrated lime gave as good results as sulfur. Anderson & Walker (1937), using for experimental purposes a heavily infested field of strawberries that had been severely injured by frost and drought, obtained increases in yield ranging from 35 to 62 per cent with lead arsenate and lime (1:5), lead arsenate and sulfur (1:5), derris and sulfur (0.75 per cent rotenone), and salcium arsenate and sulfur (1:5), listed in the order of their effectiveness. Amos

[1] Acknowledgments are made to C. F. Stahl for suggestions, and to L. B. Reed, F. W. Wright, and H. N. Pollard for assistance in the work in this project.

& Pierpont (1939) reported that in field experiments calcium arsenate gave better results than lead arsenate, that the diluent was relatively unimportant, and that in one experiment both lead arsenate-sulfur (1:5) and a 0.5-per cent rotenone dust gave a control of 24 per cent, as represented by the increase in uninjured buds.

conditions permitted after the weevils had begun to cut the fruiting buds.

In the experiments conducted from 1929 to 1932, inclusive, the efficiency of the insecticides was judged by the relative number or percentage of cut buds found by examining 100 row-feet of plants in the center of each plot at intervals after applying the insecticides. In the experi-

**Table 1.—Effectiveness of various insecticidal treatments in the control of the strawberry weevil on strawberries at Chadbourn, N. C., 1925–32.**

| Treatment | Rate per Acre per Application | Control[1] |
|---|---|---|
| | *Pounds* | *Per Cent* |
| 1925, 2 applications, 2 replicates, 4-row plots 100 feet long: | | |
| Calcium arsenate 17%, sulfur | 15 | 76 |
| Lead arsenate 17%, sulfur | 15 | 76 |
| Calcium arsenate 20%, dehydrated copper sulfate 16%, hydrated lime | 12 | 60 |
| Lead arsenate 20%, dehydrated copper sulfate 16%, hydrated lime | 12 | 50 |
| Calcium arsenate 14%, dehydrated copper sulfate 12%, hydrated lime | 12 | 49 |
| Lead arsenate 10%, dehydrated copper sulfate 6%, hydrated lime | 12 | 31 |
| Calcium arsenate 10%, dehydrated copper sulfate 6%, hydrated lime | 12 | 30 |
| Lead arsenate 14%, dehydrated copper sulfate 12%, hydrated lime | 12 | 27 |
| 1926, 1 application, 2 replicates, 4-row plots 150 feet long: | | |
| Calcium arsenate 17%, sulfur | 20 | 80 |
| Calcium arsenate 20%, dehydrated copper sulfate 16%, hydrated lime | 15 | 64 |
| Calcium arsenate 14%, dehydrated copper sulfate 10%, hydrated lime | 15 | 61 |
| Lead arsenate 14%, dehydrated copper sulfate 10%, hydrated lime | 15 | 57 |
| Lead arsenate 20%, dehydrated copper sulfate 16%, hydrated lime | 18 | 52 |
| Calcium arsenate 10%, dehydrated copper sulfate 6%, hydrated lime | 15 | 26 |
| Calcium fluosilicate | 15 | 16 |
| Lead arsenate 10%, dehydrated copper sulfate 6%, hydrated lime | 15 | 15 |
| 1929, 2 applications, 2 replicates, 17-row plots, 52 feet long: | | |
| Calcium arsenate 17%, lime 17%, sulfur | 25 | 40 |
| Calcium arsenate 17%, sulfur | 25 | 36 |
| Pyrethrum[2] spray (1:200) | 76[3] | 20 |
| Pyrethrum[2] spray (1:400) | 76[3] | 15 |
| Lead arsenate 17%, sulfur | 29 | 4 |
| 1931, 2 applications, 3 replicates, 6-row plots, 100 feet long: | | |
| Calcium arsenate 17%, sulfur | 12 | 84 |
| Potassium hexafluoaluminate 17%, sulfur | 14 | 79 |
| Lead arsenate 17%, sulfur | 16 | 79 |
| 1932, 2 applications, 4 replicates, 6-row plots, 100 feet long: | | |
| Calcium arsenate 17%, sulfur | 15 | 52 |
| Potassium hexafluoaluminate 17%, sulfur | 15 | 67 |
| Pyrethrum powder[2] | 10 | 67 |
| Lead arsenate 17%, sulfur | 15 | 43 |
| Sulfur | 15 | 33 |

[1] Decrease in weevil-cut buds as compared with those in undusted plots.
[2] Pyrethrins content not known.
[3] Gallons of spray mixture.

The purpose of this article is to summarize the results of experiments conducted during the period 1920 to 1938, inclusive, at Chadbourn, N. C., and in 1939 on the Eastern Shore of Maryland.

METHODS.—The insecticides were applied to replicated plots by means of rotary hand dusters or hand-pressure sprayers. Two or three applications were made as needed, beginning as soon as weather

ments prior to 1925, 100 plants were examined, rather than the plants on 100 row-feet. It was not possible to find the dead weevils and to determine the percentage of mortality, owing to the small size of the insect and its color and to the practice among growers of applying a pine-leaf mulch to the fields about the time the weevils become active. Usually two or more replicates were made in

different fields.

The experiments conducted in 1935 to 1939, inclusive, were arranged in either randomized blocks or latin squares with six replicates in each. Beginning with the 1936 experiment, sampling areas were located on the three central rows of each plot by use of random sampling numbers at the beginning of the experiment, and were staked so that they could be readily identified. By frequent examination of these areas records were made of the number of buds produced, the number cut by the weevil, and the number that developed into berries. At harvest time the berries were picked by the grower, as in commercial practice, but the fruits from the sampling areas were kept separate, the culls were removed, and the marketable berries were counted and weighed. The efficiency of the insecticides was judged by the percentage reduction in cut buds and the percentage increase in the weight of marketable berries, as compared with the untreated plots.

RESULTS.—During 1920 and 1922 tests were made of undiluted lead arsenate and of different mixtures with sulfur. Results were usually good from the standpoint of reduction in cut buds but were not always satisfactory in so far as the effect on yield was concerned. Most promising results were obtained with a mixture of 1 part by weight of lead arsenate and 5 parts of sulfur. A dust containing 2 per cent of nicotine sulfate and lime was tested, with poor results.

During the period 1925 to 1932, inclusive, calcium arsenate and lead arsenate were compared in various mixtures with sulfur and with both hydrated lime and dehydrated copper sulfate. The results, given in table 1, show that calcium arsenate was more effective than lead arsenate and that sulfur was a better diluent for this material than was a mixture of dehydrated copper sulfate and lime. Calcium fluosilicate was relatively ineffective, as was pyrethrum, applied in a spray of an unknown pyrethrins content. Promising results were obtained with potassium hexafluoaluminate and also with undiluted pyrethrum powder.

In an experiment on dewberries with four replicates in 1931, from 56 to 68 per cent control was obtained with potassium hexafluoaluminate, calcium arsenate, lead arsenate, and pyrethrum. All materials except the pyrethrum were mixed with sulfur in the ratio of 1:5. Two applications were made at rates ranging from 20 to 32 pounds per acre.

The experimental work was discontinued in 1932, but was resumed in 1935 in order to test ground derris root and to test more thoroughly the value of pyrethrum powder, as both these materials can be used at any time without leaving harmful residues on the marketed fruit. Another objective was to obtain information on the increase in yield and profit to the grower following the use of insecticides for weevil control. The yields of marketable berries in successive years from 1935 to 1939, inclusive, in the undusted plots of the experiments were 2170 2400, 1161, 254 and 2252 quarts per acre, The yield of only 254 quarts per acre in the 1938 experiment made the results for that season very unsatisfactory and of questionable value. The insecticidal mixtures tested, the weevil control, and the effect on the yield are summarized in table 2.

In 1935 the calcium arsenate-sulfur (1:5) mixture was compared with 2 strengths each of pyrethrum powder and ground derris. Derris reduced the number of weevil-cut buds 42 per cent, and the plants dusted with this material looked much healthier than those dusted with calcium arsenate and sulfur. The latter was much more effective, however, from the standpoint of reduction in cut buds, and for the season as a whole it gave 70 per cent control. The number of cut buds found on 600 feet of row following the third application was 257 in the calcium arsenate plots, as compared with 1044 in the derris (1 per cent rotenone) plots and 1797 in the undusted plots. At that time the leaves that had been treated with the calcium arsenate-sulfur mixture were slightly crinkled and appeared lifeless and papery in comparison with the others in the experiment, and the growth of the plants was somewhat retarded. The foliage injury may have been due to the conditioned sulfur used in this experiment. The conditioning agent added to the sulfur during the manufacturing process is not known.

The yield of marketable berries in the 1935 experiment was disappointing, as none of the insecticidal treatments were appreciably affected by it. It is possible

**Table 2.—Strawberry weevil control and the increase in yield of Klondike strawberries following the use of insecticides at Chadbourn, N. C., 1935–39.**

| TREATMENT | RATE PER ACRE PER APPLICATION | CONTROL[1] | INCREASE IN YIELD |
|---|---|---|---|
| | *Pounds* | *Per Cent* | *Per Cent* |
| 1935, 3 applications, 6 replicates, 5-row plots, 112 feet long: | | | |
| Calcium arsenate 17%, sulfur | 35 | 70 | 0 |
| Derris and clay (1% rotenone) | 15 | 42 | 8 |
| Derris and clay (0.5% rotenone) | 12 | 31 | 8 |
| Pyrethrum and clay (0.25% pyrethrin I) | 15 | 21 | 3 |
| Pyrethrum and clay (0.12% pyrethrin I) | 12 | 9 | 9 |
| Difference required for significance (odds 19:1) | — | 31 | (2) |
| 1936, 2 applications, 6 replicates, 5-row plots, 57 feet long: | | | |
| Calcium arsenate 17%, sulfur | 32 | 48 | −13 |
| Pyrethrum and clay (0.1% pyrethrin I) | 14 | 41 | −13 |
| Pyrethrum and clay (0.05% pyrethrin I) | 8 | 25 | − 3 |
| Derris and clay (1% rotenone) | 10 | 13 | − 5 |
| Derris and clay (0.5% rotenone) | 7 | 6 | 8 |
| Difference required for significance (odds 19:1) | — | (2) | (2) |
| 1937, 3 applications, 6 replicates, 5-row plots, 50 feet long: | | | |
| Calcium arsenate 17%, sulfur | 22 | 60 | 9 |
| Sulfur 83%, lime | 17 | 30 | 18 |
| Derris and clay (1% rotenone) | 11 | 13 | 9 |
| Derris and clay (0.5% rotenone) | 12 | 9 | 19 |
| Pyrethrum and clay (0.2% pyrethrins) | 16 | − 2 | 10 |
| Difference required for significance (odds 19:1) | — | 31 | 16 |
| 1938, 1 to 3 applications,[3] 6 replicates, 5-row plots, 44 feet long: | | | |
| Calcium arsenate 17%, sulfur | 29 | 11 | 10 |
| Sulfur | 25 | − 5 | 33 |
| Calcium arsenate 17%, tobacco dust | 14 | − 8 | 48 |
| Cryolite and tobacco dust (21% sodium fluoaluminate) | 12 | − 8 | 0 |
| Tobacco dust (X grade) | 15 | −11 | −10 |
| Cryolite and sulfur (21% sodium fluoaluminate) | 25 | −26 | 49 |
| Difference required for significance (odds 19:1) | — | (2) | (2) |
| 1939,[4] 3 applications, 6 replicates, 5-row plots, 50 feet long: | | | |
| Cryolite, undiluted (85% sodium fluoaluminate) | 17 | 69 | −21 |
| Cryolite and sulfur (42% sodium fluoaluminate) | 21 | 64 | 2 |
| Calcium arsenate 17%, sulfur | 24 | 44 | 7 |
| Pyrethrum and pyrophyllite (0.18% pyrethrins) | 37 | 11 | 12 |
| Nicotine bentonite (3 per cent nicotine) | 27 | 4 | − 4 |
| Difference required for significance (odds 19:1) | — | 17 | (2) |

[1] Decrease in weevil-cut buds, as compared with those in undusted plots.
[2] Differences between treatments not significant according to the *F* test.
[3] Each mixture applied once, twice, and three times on two plots each.
[4] Conducted on Dorsett strawberries in Maryland near Pocomoke City.

that the calcium arsenate-sulfur mixture caused sufficient injury to the plants to offset the benefits derived from the control of the strawberry weevil. It is known, however, that the strawberry plant produces many more buds than can develop into marketable fruit, and it is reasonable to assume that the control of the weevil will not affect the yield unless the weevil cuts enough buds to affect the crop materially. Unfortunately, neither the total number of buds nor the number of marketable berries was recorded.

In the experiments conducted in 1936, 1937, and 1939 the total numbers of buds and marketable fruits were recorded; therefore, the percentages of the buds cut by the weevil and of those that made marketable fruit could be calculated. These percentages offer a reasonable explanation as to why the weevil control obtained in the experiments failed to increase the yield materially. As shown in table 3, the strawberry weevil destroyed only 8 to 21 per cent of the buds, and some of these were destroyed before the insecticides were applied. In 1936 a late frost killed the buds and fruit after much of it had set. The experiment was conducted on buds produced after the frost. This second crop was estimated to be of about the same size as the first crop. Only 69 per cent of the second crop of buds made marketable fruit, and only 8 per cent were cut by the weevil. This left a surplus of 23 per cent that failed to develop into marketable

berries and yet were not destroyed by the weevil. This percentage would no doubt have been much higher had not the first crop of buds and fruit been killed by frost. In 1937 there was 63 per cent of surplus buds, and in 1938 there was 57 per cent. It is not surprising, therefore, that applications of the calcium arsenate-sulfur mixture giving 70 per cent control or less (Table 2) failed to increase the yield materially. It appears from these studies that insecticidal control of the strawberry weevil would not be warranted in fields in which fewer than 25 per cent of the buds are expected to be cut. Unfortunately, there is no known method of determining what percentage will be cut in time to apply insecticides.

**Table 3.—Buds cut by the strawberry weevil in control experiments, as compared with buds that made marketable fruit.**

| Insecticide Applied | Year | Buds Cut by Weevil | Buds that Made Marketable Berries |
|---|---|---|---|
| | | *Per Cent* | *Per Cent* |
| Calcium arsenate 17 per cent, sulfur | 1936 | 5[1] | 62[2] |
| | 1937 | 8[1] | 27 |
| | 1939 | 14 | 28 |
| None (check) | 1936 | 8 | 69[2] |
| | 1937 | 15 | 22 |
| | 1939 | 21 | 22 |

[1] Includes some buds cut in 1936 and 1937 before insecticides were applied.
[2] Based on the number of buds produced after a late frost, which killed about half the potential crop.

As shown in table 2, neither derris nor pyrethrum was very effective, although a mixture containing pyrethrum was shown by Pollard and Thomas (1942) to be very toxic under laboratory conditions. In 1938 unsatisfactory control was obtained with each of the insecticides tested, including the mixture of calcium arsenate and sulfur, but unfortunately the experiment was conducted on a very uneven stand of strawberries, and the weevil population was uneven and insufficient to cut over 18 per cent of the buds produced on the 12 undusted plots. In 1939 very promising results were obtained with undiluted cryolite and a mixture of cryolite and sulfur containing 42 per cent of sodium fluoaluminate. Nicotine bentonite was not effective.

Under the conditions of these studies it was not possible to obtain experimental data of value concerning the time to apply insecticides.

SUMMARY.—Experiments were conducted on the insecticidal control of the strawberry weevil. Best results were obtained with arsenical and fluorine compounds but none of these were very satisfactory. The control of relatively light infestations of the weevil did not result in appreciable increases in yield. The strawberry plants produced a large percentage of surplus buds that did not make marketable berries, and apparently a small amount of pruning by the weevil did not adversely affect the yield. Derris, sulfur, and pyrethrum were less effective than were calcium arsenate and cryolite. Nicotine bentonite was not effective.—6-1-45.

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## CAPT. W. E. MCCAULEY

The many friends of Captain W. E. McCauley will be pleased to learn of his return to this country after three years service with Sanitary Corps in the South Pacific. Mr. McCauley has resumed his work as entomologist with the Velsicol Corporation of Chicago, manufacturers of insecticides, resins, solvents, and other petroleum chemical derivatives.

# The Synergistic Action of *N,N*-Diethylpiperonylamide with Pyrethrum Marc in Control of the Mexican Bean Beetle

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In the extraction of ground pyrethrum flowers with various solvents for the preparation of pyrethrum extracts and concentrates, a small amount of the pyrethrins is left in the marc. Prior to the war this residual product was burned by manufacturers, since it had little value. With the recent shortage of critical materials the marc has been finding some use as a diluent, expecially for powders of high pyrethrin content.

It has been found that the efficacy of the pyrethrins against certain insects is greatly enhanced by the addition of synergists, some of which have been found to boost their toxicity to several times the original value. According to results reported by Gertler *et al.* (1943 *a*, *b*), and Gersdorff & Gertler (1944), *N*, *N*-diethylpiperonylamide has shown marked synergistic action when used with small amounts of pyrethrins in a fly spray against houseflies. *Musca domestica* L. David & Bracey (1944) reported the synergistic action of *N*-isobutylundecylenaemide with pyrethrins in fly sprays when used against the yellow-fever mosquito, *Aedes aegypti* (L.).

In order to obtain data which might prove of value in the utilization of the waste pyrethrum marc for practical insecticidal purposes, a number of compounds which were thought to possess some synergistic or other desirable property were tested with the marc. These tests were made at Beltsville, Md., in 1944.

Experimental Procedure.—Unless otherwise indicated, the dust mixtures used in these tests were prepared to contain 60 per cent of pyrethrum marc, 38 per cent of pyrophyllite, and 2 per cent of the compound to be tested. Third instars of the Mexican beetle, *Epilachna varivestis* Muls., were usually employed as the test insects. These larvae were reared under greenhouse conditions on bean plants (variety Cranberry) growing in 4-inch plots. In order to get some information as to whether the toxic effect of the mixture was due to stomach of contact action, two methods of testing were used. In one method 10 larvae were transferred to the plant, and after they became settled the insecticide was applied; in the other method the plants were dusted with the mixture, and then the larvae were placed on the treated foliage. After being dusted, the plant was covered with a celluloid cage which was protected with cheesecloth to prevent the escape of larvae. Some of these cages were provided with small side screens near the bottom to increase ventilation. The cages were kept under observation usually for 96 hours before the mortality was determined, and longer periods in some instances. In some of the tests the larvae were not confined in cages.

The insecticidal dusts were applied either with hand dusters or with small applicators improvised from atomizer bulbs with tubing and small vials as containers for the insecticide. The latter proved satisfactory for treating individual plants. No measured dosages were used, but an effort was made to apply an even coating on all plant surfaces and also to the larvae placed on the foliage prior to treatment.

Greenhouse Experiments.—In the first experiment 1-chloro-2[2-(2,3,4,6-tetrachlorophenoxy)ethoxy]ethane and *N*, *N*-diethylpiperonylamide were tested as synergists with pyrethrum marc. Six replications were made between February 23 and March 16.

Soon after the dusts had been applied the larvae, whether placed on the plant before or after treatment, were greatly irritated, and many dropped to the soil, where they remained in a somewhat moribund state. The larvae that were treated with the mixture of pyrethrum marc and 1-chloro-2[2-(2,3,4,6-tetrachlorophenoxy) ethoxy]ethane and with the pyrethrum marc alone eventually recovered, as many crawled back and reestablished themselves on the plant, where they resumed normal feeding and development. Among the larvae treated with the dust containing *N,N*-diethylpiperonylamide, however, a few individuals recovered temporarily and did a small amount of feeding, but 97 per cent were dead 96 hours after treatment and eventually all died. When the larvae

were placed on the foliage after the dust had been applied, they were not so seriously affected and the mortality was not so high, being 57 per cent on foliage treated with the dust containing *N,N*-diethylpiperonylamide. In each of two replications one adult emerged. In the untreated checks the larvae fed so voraciously that the plant was completely defoliated, and a fresh plant had to be supplied to furnish sufficient food for the remainder of the test period.

To determine the possibility of fumigating action in these tests on caged plants, additional tests with the same dust mixtures were conducted on uncaged infested plants. For each test an 8-inch shallow flowerpot containing several bean plants was allowed to become infested with bean beetle larvae and then dusted. This pot was left entirely unprotected, so that any fumes which might possibly be given off by the insecticide would be dissipated. The pot of treated plants was then held for observation in a shallow pan, the rim of which was coated with Vaseline or Tanglefoot to prevent the escape of any larvae that fell from the plant. Despite this precaution some of the larvae crawled over this sticky barrier and were lost. No untreated checks were used in these tests, since it is known that larvae develop normally under such conditions. The results of two series of tests are given in table 1.

It is apparent from the results shown in table 1 that the dust containing *N,N*-diethylpiperonylamide was definitely the most effective. The other two treatments were of no value. There was considerable feeding on the plants that received these two treatments, but none on those treated with the dust containing *N,N*-diethylpiperonylamide. Although the data are too meager to permit one to draw definite conclusions, the indications are that slight fumigation effect may have occurred in the test where the plants were caged, since in that test the mortality was slightly higher from the *N,N*-diethylpiperonylamide mixture, which was the more effective treatment.

In a third series of tests the same treatments were given to nearly full grown larvae on caged plants. Soon after application most of the larvae in all three treatments dropped to the ground. These larvae were returned to the foliage, where they did very little feeding and soon began to pupate; eventually most of them emerged as adults. Of the larvae receiving the *N,N*-diethylpiperonylamide dust only one died.

To determine whether the compound itself was toxic, each test was replicated

**Table 1.—Mortality of Mexican bean beetle larvae on uncaged plants 96 hours after treatment with pyrethrum marc, with and without the synergist indicated; larvae on plants before treatment.**

| Date Treated | Synergist | Total Larvae | Escaped Larvae | Mortality | Amount of Feeding |
|---|---|---|---|---|---|
| | | *Number* | *Number* | *Per Cent* | |
| Feb. 29 | 1-Chloro-2[2-(2,3,4,6-tetrachlorophenoxy)-ethoxy]ethane | 21 | 16 | 14 | Plants defoliated |
| | *N,N*-Diethylpiperonylamide | 37 | 5 | 84 | None |
| | None | 13 | — | 15 | Plants defoliated |
| Mar. 13 | 1-Chloro-2[2-(2,3,4,6-tetrachlorophenoxy)-ethoxy]ethane | 21 | 8 | 0 | Severe[1] |
| | *N,N*-Diethylpiperonylamide | 16 | 6 | 62 | None |
| | None | 17 | — | 12 | Severe[2] |

[1] 3 adults.
[2] 5 adults, 3 pupae.

**Table 2.—Mortality of larvae of Mexican bean beetle on caged plants 96 hours after treatment with dusts containing *N,N*-diethylpiperonylamide, pyrophyllite, and pyrethrum marc in various combinations. Average of six replications, May 11 to 25.**

| Treatment | Average Mortality When Larvae Were Placed on Plants | |
|---|---|---|
| | Before Treatment | After Treatment |
| | *Per cent* | *Per cent* |
| *N,N*-Diethylpiperonylamide, pyrethrum marc, pyrophyllite (2:60:38) | 77 | 52 |
| *N,N*-Diethylpiperonylamide, pyrophyllite (2:98) | 15 | 13 |
| Pyrethrum marc, pyrophyllite (60:40) | 17 | 8 |
| Check (no treatment) | 1.7 | 1.7 |

six times from May 11 through May 25. Series of cage tests were performed in which a mixture of *N,N*-diethylpiperonylamide and pyrophyllite, a mixture of pyrethrum marc and pyrophyllite, and a mixture of all three of these materials were compared. As shown in table 2, the toxicity of the three-component mixture was much greater than that of either two-component mixture.

In some replications a few of the larvae were larger than the others, and in several of these pupation began before the end of the 96-hour observation period. In the checks all larvae except one completed their normal development, and several emerged as adults.

Several other compounds were also tested for possible synergistic action under the same experimental conditions. In these tests the larvae were placed on the plants before the treatments were applied.

The average results of six replicated tests, the first on March 24 and the last on April 17, as given in table 3, show that none of these materials was of any value with the possible exception of *N*-amylbenzamide. The degree of larval feeding ranged from slight to severe.

**Table 3.—Mortality of Mexican bean beetle larvae on caged plants 96 hours after treatment with pyrethrum marc alone and with various compounds tested for synergistic action; larvae placed on plants before treatment. Average of six replicates.**

| Compound | Average Mortality | Larva Continuing Development to[1] | |
|---|---|---|---|
| | | Pupae | Adults |
| | *Per cent* | *Number* | *Number* |
| N-Butylbenzamide | 32 | 4 | 3 |
| N-Amylbenzamide | 50 | 2 | 7 |
| Ethylmethyl ketone semicarbazone | 22 | 2 | 6 |
| 4-Methylcyclohexanone semicarbazone | 15 | 2 | 5 |
| N-Isobutylundecyleneamide | 22 | 1 | 3 |
| Ethylene glycol ether of pinene | 17 | 1 | 5 |
| Pyrethrum marc | 17 | 1 | 6 |
| No treatment | 1 | 1 | 9 |

[1] First replication only.

In the first replication the cages were held longer than 96 hours to determine whether the surviving larvae would continue their development to the adult stage. The data, also shown in table 3, verify the fact that none of these materials had any significant toxic effect.

Incidental tests were also conducted with two additional compounds, 3,4-methylenedioxybenzyl-*n*-propyl ether and alpha-(*n*-propyl)piperidine as synergists for pyrethrum marc. The mortality with the first material was 90 and with the second material 100 per cent, when the larvae were placed on caged plants before the dusts were applied. In the tests with uncaged plants a lower kill resulted. Because of the severe injury to the plants, however, no further tests for these two compounds were warranted.

OUTDOOR TESTS.—In small .plots of beans, each consisting of one 10-foot row, a mixture containing 60 per cent of pyrethrum marc and 2 per cent of *N,N*-diethylpiperonylamide was compared with cube dust containing 0.5 per cent of rotenone. The plots, arranged in five randomized blocks, were dusted with the mixture on July 27 and August 4, 14, and 25. On August 14, just before the third application, 67 Mexican bean beetle larvae were counted on 10 trifoliate leaves taken at random from each of the plots treated with the pyrethrum-marc mixture and 2 larvae on a similar sample from the plots treated with rotenone. Twelve days later, or 1 day after the last application, the infestation had been reduced to 8 and 0 larvae for the two treatments, respectively. In untreated check plots there were 66 larvae on August 14 and 109 on August 26.

Observations following an application of the pyrethfum-marc mixture on September 15 showed that within 2 hours most of the larvae and adults of the bean beetle were on the ground in a moribund condition. By the next day some of them had returned to the plants whereas others had been carried away by ants. Of 71 individuals collected the day after treatment and placed on untreated plants in the laboratory for observation, 62 per cent were dead after 7 days.

CONCLUSIONS.—The results of the tests show that *N,N*-diethylpiperonylamide is a synergist for pyrethrum marc when used against the Mexican bean beetle. This material appears to act as a paralytic agent rather than a stomach poison. Since the affected insects drop to the ground, any factor such as extreme heat or direct sun would tend to kill them more readily. Further tests should be made on a larger scale, not only against the Mexican bean beetle, but also against other insects that may be controlled with pyrethrum.—8-8-45.

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# Airplane Spraying of Rice Fields with DDT to Kill Mosquito Larvae

C. B. WISECUP,[1] WILLIAM C. BROTHERS,[2] and PAUL M. EIDE[1]

Preliminary studies at the Orlando, Florida, laboratory of the Bureau of Entomology and Plant Quarantine (Deonier *et al.* 1945, and Wisecup *et al.* 1945) had demonstrated that DDT (1-trichloro-2, 2-bis (*p*-chlorophenyl) ethane) was very effective for the control of *Anopheles* and *Psorophora* mosquito larvae, and that applications could be made from liaison-type airplanes (Deonier *et al.* 1945). In order to assist the Surgeon General's Committee on DDT in making recommendations on the use of airplane spraying with DDT as a means of controlling mosquitoes, a series of large-scale tests was conducted in the rice-growing area of east-central Arkansas from May 25 to September 4, 1944. The rice fields surrounding the Army Air Field near Stuttgart were selected for these tests.

The system of rice growing practiced in Arkansas provides for an initial flooding of the young rice early in June, a short period of drying for the control of the rice water weevil, *Lissorhoptrus simplex* (Say), and an attempt at prolonged flooding throughout July and August. Since it is frequently impossible to maintain an unbroken body of water at this second flooding, a series of floodings usually occurs. Situations such as these provide ideal conditions for the development of large broods of floodwater mosquitoes of the genus *Psorophora*. Most periods of flooding, and especially the last one, are of sufficient duration for large broods of *Anopheles quadrimaculatus* Say to emerge.

The development of DDT provided a material which showed promise for use in several ways in controlling the principal species of rice-field mosquitoes. Tests were conducted during the season to determine the efficiency of this insecticide when applied for initial control of *Anopheles* and *Psorophora* larvae, as a preflooding treatment for the control of these larvae, and at heavy dosages to determine its residual effect as a larvicide.

METHODS.—All spraying was done with a Husman-Longcoy portable spray unit for liaison-type airplanes. Airplanes of the Army designation *L-2* (Taylorcraft), *L-3* (Aeronca), and *L-4* (Piper Cub) were used. Because of possible damage to rice by sprayed oils, all treatments were made with an aqueous emulsion containing either 5 or 10 per cent of DDT, made from a concentrate consisting of 25 per cent of DDT, 68 per cent of xylene, and 7 per cent of *Triton X-100* (an aralkyl polyether alcohol).

Because of the open nature of the country in eastern Arkansas, it was possible to fly rather low and in regular pattern. All treatments were made with swaths 40 feet wide, the line of flight being marked by flagmen at each end of the field. Flying was always cross-wind, beginning at the leeward side of the field and working upwind. Applications were made at any time of day that the winds were sufficiently safe for flying light aircraft. It was evident that the water emulsion was heavy enough to descend in regular swaths with a minimum drift when applied in winds up to 15 miles per hour.

The effectiveness of any treatment for

[1] Entomologists, U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, working under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development.

[2] Lieutenant, Sanitary Corps, U. S. Army Air Forces. Equipment and some personnel were supplied by the Stuttgart Army Air Field, Eastern Flying Training Command, U. S. Army Air Forces; the Corps of Engineers of the Eighth Service Command; the Office of the Chief of Engineers, and the Office of the Surgeon General, U. S. Army.

initial control was determined by comparing pretreatment and 24-hour dipping records in the treated field; of preflooding treatments by comparing dipping records from similar treated and untreated fields; and of residual applications by comparing weekly dipping records.

RESULTS.—The results obtained during the season are summarized in table 1. Because of the perfect initial control of *Anopheles* larvae which was being obtained with dosages as low as 0.1 pound of DDT per acre, slight attention was paid to this objective during July and August. Observations of less than perfect initial control in August prompted the making of two tests in fields of mature rice that provided extremely heavy vegetative protection to larvae. For these tests a more powerful Stearman (*PT-17*) biplane equipped with spray apparatus similar to that developed for the Cub was used.

Perfect control of *Psorophora* larvae was obtained with all applications except with one lot of DDT applied on July 11 and 15.

If airplane applications for area control are to be economical in situations of frequent flooding and drying such as occur in rice-growing districts, it is essential that large areas be treated irrespective of the larval populations at the time. This would involve determining the effects of preflooding treatments on dry fields prior to flooding, and the residual effects of the treatment on flooded fields. Preflooding treatments involving at least 0.2 pound of DDT per acre prevented the development of *Psorophora* larvae, although an extremely large population of newly hatched larvae was frequently noted on the day after the field was flooded. Preflooding treatments of less than 0.5 pound of DDT per acre appeared to be of doubtful value against *Anopheles*, although for several weeks after flooding few anopheline larvae were found that had developed beyond the second instar.

The duration of any residual action against *Anopheles* was determined by the period over which a field was free of any larvae. Thus the periods of 2 to 4 weeks of effective residual action shown in table 1 represent the time between treatment and the finding of the first small larvae. It was again apparent that, although breeding had been resumed, the production of large numbers of adults was definitely inhibited.

**Table 1.—Results of airplane treatments of rice fields with DDT emulsions.**

| Dosage Per Acre | | | Area Treated | Initial Control | | Preflooding Control | | Duration of Residual Effect |
|---|---|---|---|---|---|---|---|---|
| Liquid | DDT | Date | | *Anopheles* | *Psorophora* | *Anopheles* | *Psorophora* | |
| *Quartz* | *Pounds* | *1944* | *Acres* | *Per Cent* | *Per Cent* | | | *Weeks* |
| 1.4 | 0.14 | June 15 | 15 | 100 | 100 | — | — | — |
| 2.0 | .2 | 23 | 75 | 100 | — | — | — | — |
| | | July 1 | 15 | — | 100 | None | Fairly efficient | — |
| | | | 20 | 100 | — | Doubtful | Fairly efficient | Less than 3 |
| | | 5 | 43 | 100 | 100 | — | — | — |
| | | 6 | 36 | — | — | Doubtful | Very efficient | About 2 |
| 1.0 | .1 | | 55 | 100 | 100 | — | — | — |
| | | | 25 | — | — | Doubtful | Doubtful | — |
| 2.0 | .2 | 11 | 55 | — | — | Doubtful | Very efficient | — |
| | | | 65 | — | — | — | — | — |
| | | | 60 | — | 97 | Doubtful | Very efficient | Less than 2 |
| | | 15 | 3 | — | 90[1] | — | — | — |
| | | 22 | 16 | — | 95[1] | — | — | — |
| 4.0 | .5 | | 34 | — | — | Good | Very efficient | 4 |
| | | 27 | 15 | — | — | — | — | 4 |
| | | | 20 | — | 100 | — | — | 3 |
| | .95 | 28 | 15 | — | 99 | — | — | 3 |
| | .5 | Aug. 4 | 30 | — | 100 | — | — | 2 |
| | | 11 | 23 | — | 100 | Doubtful | Complete | 2 |
| | .95 | | 30 | — | 100 | — | — | More than 3[3] |
| 1.7 | .2 | Sept. 2[2] | 10 | 100 | — | — | — | — |
| | | | 15 | 100 | — | — | — | — |

[1] Treatments with another lot of DDT applied on the same dates gave 100 per cent control.
[2] Tests made with Stearman (*PT-17*) biplane.
[3] Project terminated early in September.

DISCUSSION.—With the Husman-Longcoy spray apparatus no discernible difference in results could be noted between applications from the *L-2*, *L-3*, or the *L-4* liaison types of airplanes. Only slight modifications in the supporting brackets of the apparatus were necessary for it to be installed easily in any of the three types of light planes, changes which could readily be made by any group of mechanics.

Five Army Air Forces pilots, most of whom had little experience with this type of airplane and none of whom had done any crop dusting, all made satisfactory applications after a single test flight. It was evident that any Air Forces pilot can be quickly taught the fundamentals of mosquito-control flying, at least in open country without trees or other obstacles, such as was found in the Stuttgart area.

More time was spent in servicing the airplane than was spent in the air. The 25-gallon tank was sufficiently large when applications of 0.1 to 0.2 pound of DDT per acre for initial kill were being made, but was too small for the application of heavier dosages. The emulsion seriously rusted all iron pieces of equipment, but did not affect the aluminum tank or the brass pump. The spray boom, cut-off valve, and filler cap were the only parts requiring replacement during the season.

No damage to developing rice could be observed during the season. Random counts of heads of rice from treated and untreated portions of several fields showed no difference in the number of plump grains that had been produced.

SUMMARY.—Large-scale tests to determine the effectiveness of airplane spraying with DDT in achieving larval control of both *Anopheles* and *Psorophora* mosquitoes were conducted during the summer of 1944 in the rice fields adjacent to the Army Air Field near Stuttgart, Arkansas. A water emulsion containing 5 or 10 per cent of DDT was prepared from a concentrate containing 25 per cent of DDT, 68 per cent of xylene, and 7 per cent of *Triton X-100*. Applications were made with liaison-type airplanes to more than 700 acres of growing rice. The following results were obtained:

(1) The DDT-xylene-*Triton X-100* emulsion could be sprayed satisfactorily from an airplane.

(2) *Anopheles* larvae were readily killed by application of 0.1 to 0.2 pound of DDT per acre, but preflooding treatments at these dosages were of doubtful value against these larvae.

(3) Larvae of *Psorophora* spp. were killed by direct application of sprays containing from 0.1 to 0.2 pound of DDT per acre.

(4) Similar light dosages gave good control of the larvae of *Psorophora* when applied before the fields were flooded.

(5) Dosages greater than 0.5 pound of DDT per acre tended to give control of all mosquito larvae for about a month.

(6) No damage to rice was observed as a result of these applications.

(7) Liaison-type airplanes of the Army designations *L-2*, *L-3*, and *L-4* were equally satisfactory for spraying.

(8) No special training was necessary for service pilots to make airplane applications in open country.—10-3-45.

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## DR. L. C. MCALISTER

Dr. L. C. McAlister has joined the research staff of Dodge and Olcott, of New York City. Dr. McAlister will be associated with Dr. W. E. Dove in carrying on entomological research in the laboratories of the Company. Dr. McAlister was formerly a member of the Bureau of Entomology and Plant Quarantine and has recently participated in the studies of DDT in the Orlando, Florida, laboratories of the Bureau.

# DDT Penetration Prevented by Adding Aluminum Stearate to DDT-Kerosene Solutions

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In order to retard the rate of penetration of kerosene into the various parts of the citrus tree, the writer (Ebeling 1941) has added 1 per cent or less of aluminum stearate. More recently interest in retarding the rate of penetration of kerosene into the tree was revived by the possibility that DDT dissolved in kerosene might be more efficiently deposited on the tree surface if the kerosene were prevented from penetrating, thus evaporating and leaving the DDT crystals on the surface. The extent to which the amount of DDT remaining on the tree surface may be increased is shown in figure 1. The left half of the figure is a photograph of a portion of the left half of the lower surface of an orange leaf to which 4 per cent by weight of DDT in kerosene had been applied, and the right half of the figure is a photograph of a portion of the right half of the same leaf to which the same solution plus 1 per cent aluminum stearate had been applied.

The kerosene solutions were applied with a camels-hair brush, 0.1 ml. being applied to each half of the leaf. The DDT-kerosene solution had completely penetrated into the leaf in less than 10 minutes, turning it dark in color. The stomata are located on the lower surface of an orange leaf and the penetration of an oil film is ordinarily very rapid. The DDT-aluminum stearate-kerosene solution, however, remained on the surface for hours, slowly leaving the surface by evaporation rather than by penetration. Obviously the kerosene solution remaining on the surface would leave more DDT on the surface than the solution which had for the most part penetrated beneath the cuticle. This can be clearly seen in figure 1.

The addition of DDT to a kerosene-aluminum stearate solution reduces the gel-forming ability of the aluminum stearate and results in a less viscous solution. To overcome this effect of the DDT the per cent of aluminum stearate may be increased from 1 per cent to 2 per cent. However a 4 per cent DDT-kerosene solution containing 1 per cent aluminum stearate appears to penetrate the lower surfaces of citrus leaves no more rapidly than the same solution with 2 per cent aluminum stearate. Likewise even 0.1 per cent aluminum stearate is also highly effective in retarding the rate of penetration of DDT-kerosene solutions. Nevertheless the following experiment was made with 2 per cent aluminum stearate solutions.

Five ml. of 4 per cent DDT in kerosene was applied to the lower surfaces of 60 orange leaves (area 2268 sq. cm.) and 4 per cent DDT in kerosene to which 2 per cent aluminum stearate had been added was applied to the lower surfaces of another 60 leaves (area 2292 sq. cm.). Next 7 ml. of the first solution was applied to 9 sections of lemon branches containing the grey, rough bark which absorbs even the films of oil deposited by the regular oil sprays very rapidly. The branches all had a similar type of absorptive surface but varied in their diameters from about 0.5 to 0.75 inch and varied in length from about 5 to 10 inches. Then 7 ml. of the second solution was applied to 9 adjacent

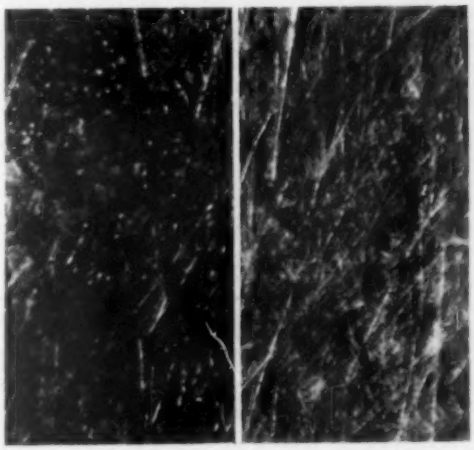

FIG. 1.—Effect of preventing the penetration of DDT-kerosene solution into the lower surface of an orange leaf by adding aluminum stearate to the solution. Left, light deposit of DDT crystals from a 4 per cent DDT-kerosene solution, because of the rapid penetration of the solution into the leaf; right, heavy deposit of DDT crystals from the same solution, after 1 per cent aluminum stearate had been added, caused by the evaporation of the kerosene on the leaf surface. ×60.

sections of branches with practically the same surface area. The surface areas of the two groups of branch sections, computed by supposing them to be perfect cylinders, were, respectively, 110 sq. in. and 107 sq. in.

The treated leaves and branch sections were kept at room temperature. Within a half hour all visible DDT-kerosene solution had penetrated into the leaves while the DDT-aluminum stearate-kerosene solution had penetrated in only a few small points. By the next morning, 20 hours later, all of the latter solution had left the leaf surfaces by evaporation.

**Table 1.—The effect of aluminum stearate in increasing the amount of DDT remaining on the surfaces of leaves and branches[1] after the disappearance of the kerosene in which the DDT was dissolved.**

| Solution | DDT on Leaf Surfaces $g./cm^2 \times 10^{-6}$ | DDT on Branch Surfaces $g./cm^2 \times 10^{-6}$ |
|---|---|---|
| Kerosene with 4 per cent DDT | 1.3 | 38.4 |
| Kerosene with 4 per cent DDT and 2 per cent aluminum stearate | 5.4 | 118.1 |

[1] Five ml. of kerosene solution containing 4 per cent DDT was applied to 2268 sq. cm. of leaf surface and 5 ml. of kerosene solution containing 4 per cent DDT and 2 per cent aluminum stearate was applied to 2292 sq. cm. of leaf surface. The surface areas of the sections of branches to which the above solutions were applied were, respectively, 110 and 107 sq. cm.

All visible traces of the DDT-kerosene solution applied to the sections of branches penetrated completely in a few minutes while some of the DDT-aluminum stearate solution could be seen on the surfaces of the branch sections 20 hours later.

The DDT on the surfaces of the leaves and branch sections was stripped with benzene and the amount removed was determined by a method devised by Gunther (1945) which involves the quantitative dehydrohalogenation of the compound. The results of the residue analyses are shown in table 1.

Table 1 shows that three to four times as much DDT is retained on the surfaces of absorptive substrata when 4 per cent DDT-kerosene solutions containing 2 per cent aluminum stearate are applied than when the same solutions not containing aluminum stearate are applied.

The use of mutual solvents to increase the amount of DDT that may be added to the oil solution affects the manner of deposition of DDT on the surface. Tetralin (tetrahydranaphthalene) and *Velsicol AR-60* (mainly methyl naphthalenes) in 10 per cent solutions in kerosene have a considerable effect themselves in retarding the penetration of the kerosene, but this effect is small compared to that of 1 per cent aluminum stearate. When these mutual solvents are used at 10 per cent concentration in kerosene to make possible the addition of 8 weight per cent DDT to the solution, the crystals of DDT left on the lower surface of an orange leaf are distributed about the leaf surface, after the kerosene has evaporated, in irregular strings, with large areas apparently free of DDT crystals. When aluminum stearate at 1 or 2 per cent is added to the DDT-tetralin-kerosene solution a much greater amount of DDT is retained on the surface and is more uniformly distributed. The crystals are arranged in a typical pattern which may be described as fan-shaped or asteroid, with the long crystals in radial lines usually 0.5 to 0.75 cm. long. On the other hand, when aluminum stearate is added to a DDT-*Velsicol*-kerosene solution the DDT remaining on the lower surface of an orange leaf is in a typical mottled pattern of groups of irregularly placed short crystals. Thus aluminum stearate affects not only the quantity of DDT deposited on the surface of an absorptive substratum, but sometimes also the pattern of crystal formation and uniformity of deposition.

Extensive field experiments are being made to determine what effect the greater retention of DDT on the tree surfaces will have on the long term effectiveness of DDT in the control of the California red scale on citrus trees.

In spraying citrus trees it has been found that the addition of 1 per cent aluminum stearate to 4 per cent DDT-kerosene used at 3 per cent concentration greatly increases the amount of DDT left on the surfaces of all parts of the tree, including the rough bark. This increase in deposit is plainly discernible. The trees sprayed with aluminum stearate-DDT-kerosene have a whitish appearance from the DDT crystals left by the evaporating kerosene, while the trees sprayed with the same concentration of DDT-kerosene but without aluminum stearate have rela-

tively few crystals on their surfaces, for the DDT is carried into the tree in solution in the rapidly penetrating kerosene. Likewise DDT dissolved in light medium spray oil also to a large extent penetrates the tree with the oil. Analyses have shown three or four times as much DDT remaining on citrus foliage when 1 per cent aluminum stearate is added to the solution than when DDT-kerosene alone is used. Similar increases are caused by the addition of the aluminum stearate when mutual solvents are used to increase the amount of DDT in the kerosene. When 1 per cent aluminum stearate is dissolved in a solution of 9 parts kerosene and 1 part tetralin containing 8 per cent DDT, the resulting solution used at 3 per cent results in a spray which leaves a heavy residue of crystals on the trees, giving them a whitish appearance that makes it possible to pick out the trees sprayed with this solution from a considerable distance. When mutual solvents of boiling points higher than kerosene are used they have a tendency to carry the DDT crystals into the tree to some extent despite the retarded penetration, and the results are not as striking as when tetralin is used as the mutual solvent.—9-18-45.

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# Dispersion of DDT Sprays from Fast Combat Aircraft[1]

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Tests at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine have shown that populations of adult salt-marsh mosquitoes may be greatly reduced by spraying solutions of DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)-ethane) from a slow-moving airplane (Lindquist *et al.* 1945). The control of mosquito larvae by this method has also been studied at this laboratory (Deonier *et al.* 1945). The success with airplane application of DDT suggested the possibility of utilizing fast combat aircraft for mosquito control in forward combat areas where the use of slow-moving planes would be impractical. Of the standard equipment immediately available in all theaters of operation, the Chemical Warfare Service M-10 tank appeared to be the most readily adaptable to the distribution of DDT sprays.

The spray tests reported here were begun in December 1943. It should be emphasized that these tests were of a preliminary nature. They were not designed to develop spraying equipment or technique, but only to determine the feasibility of using standard or slightly modified equipment on combat aircraft for controlling insects with DDT. Details of individual tests are not given, but rather a résumé with typical results.

EQUIPMENT.—The M-10 tank has a capacity of 33 gallons, but in all these tests 27.5 gallons (half of a 55-gal. drum) was used per tank. These tanks may be attached to almost any type of combat plane. The opening of the tank is 5 inches in diameter, and is closed by a glass plate, which is broken electrically by the pilot to release the contents of the tank. In ordinary use a simple cylinder or pipe is attached to serve as a nozzle. This type of nozzle was used in some tests, and for others a modified nozzle was made by drilling four V-shaped clusters of fifty quarter-inch holes in the pipe and welding four air scoops, equally spaced around the outside of the pipe, into place over the holes. These scoops were intended to direct air into the cylinder to aid in breaking up the spray.

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

The writers are indebted to Lt. Col. T. E. Enter and Capt. R. B. March, at that time, respectively, chemical officer, Army Air Forces Board, and chemical officer, Chemical Section, Operations and Training Division of AFTAC, Orlando, Fla., who directed the equipment with which the tests were made. The assistance of Lt. Col. J. Q. A. Daniels, medical inspector AFTAC, in making contacts with various units and in carrying out tests, is gratefully acknowledged.

**Table 1.—Conditions of flight and results obtained with release of solutions of DDT from M-10 tanks attached to a twin-engine, light bomber flying at 250 m.p.h.**

| Date of Test | Altitude of Plane | Cross Wind (approx.) | Tank Outlet | | Time of Discharge | Distance Covered (approx.) | Effective Swath Width[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Restriction | Nozzle | | | On Houseflies | | On *Anopheles quadrimaculatus* Larvae |
| | | | | | | | Residue in Dishes | In Cages | |
| | *Feet* | *M.p.h.* | | | *Seconds* | *Yards* | *Yards* | *Yards* | *Yards* |
| | | | | 5 per cent of DDT in fuel oil | | | | | |
| Jan. 19 | 100 | 7 | No | Modified | 7 | 850 | 150–200 | — | 200 |
| | | | | 5 per cent of DDT in fuel-motor oil | | | | | |
| 25 | 100 | 10 | No | Simple | 5.5 | 650 | 300 | 250 | 400 |
| | 100 | 10 | No | Modified | 6.2 | 750 | 250 | 250 | 400 |
| Feb. 23 | 150 | 15 | Yes | Modified | 11 | 1350 | 250+ | — | 250+ |
| 25 | 125 | 5[2] | Yes | Modified | 11–12 | 1400 | 100–150 | 50 | 200–300 |
| | | | | 10 per cent of DDT in fuel-motor oil-xylene | | | | | |
| Mar. 1 | 100 | 0–3 | Yes | Simple | 6–7 | 800 | 200–300 | 300 | 300+ |
| | 175 | 5–7 | Yes | Simple | 6–7 | 800 | 350+ | 350 | 400+ |

[1] Considered to extend from the first to the last station at which practically complete control of insects was obtained.
[2] Shifting.

A metal restriction plate was placed in front of the glass closure plate in some tests. A hole calculated to reduce the rate of flow to about one-half was drilled near one edge of the metal plate.

In all but one of the flights the plane was a twin-engine, light bomber flown at 250 m.p.h. A preliminary test was made with a single-engine fighter. One tank of solution was discharged in each test.

MATERIALS.—In most of the tests 5 per cent of DDT[1] in petroleum oil was used. Fuel oil No. 2 was used in the first tests, but later a 50:50 mixture of fuel oil No. 2 and motor oil (S.A.E. 10 or 30) was substituted. About 4 per cent of cyclohexanone was usually added to prevent crystallization of DDT during cool nights. In some tests 0.2 per cent of anthraquinone blue AB base was added for detecting the deposit on filter paper. In the last test 10 per cent of DDT was dissolved in a mixture of 30 parts of xylene and 35 parts each of fuel and lubricating oils.

EXPERIMENTAL METHODS.—Several field plans were used. In the simplest plan stations were arranged in two lines 100 yards apart at right angles to the line of flight, and were 50 yards apart in the lines. The first station was usually 50 yards from the line of flight. A third line 100 yards from and parallel with the line of flight was sometimes used to detect any variations in the rate of discharge. A line of flight was chosen as nearly as possible at right angles to the wind direction. A total of 14 test flights were made. In 9 flights DDT spray was tested against insects, but in the other flights only spray distribution was studied.

Tests were made in open terrain, except those of February 25 and March 1, in which a few of the stations were in a lightly wooded area. The spray distribution was determined from deposits on glass plates or filter papers.

To indicate the residual effect of the spray, petri dishes were placed at most of the stations to collect the DDT deposit. The dishes were taken to the laboratory, where houseflies, *Musca domestica* L. were placed in them, and observations made of the time required to cause 100 per cent knock-down, or of the percentage knock-down at the end of 2 hours. At some of the stations houseflies were exposed in small, cylindrical screen-wire cages and observations made of the mortality 24 hours after the test.

Beakers containing fourth-instar larvae of *Anopheles quadrimaculatus* Say were exposed at most of the stations, and the kill after 24 hours was observed. The conditions of the flight and the results obtained in seven of the tests see table 1.

It will be seen that, with 5 per cent of DDT in the fuel-motor oil mixture and either the simple or the modified nozzle without the restriction plate (tests of January 25), good kills of houseflies in both cages and dishes were obtained over a swath of 250 yards and of anopheline larvae over a swath of 400 yards.

The fact that the test of January 19, in

[1] All concentrations of DDT are referred to as weight per volume.

which no motor oil was added, gave a narrower effective swath may be significant. It is possible that because of evaporation the spray drifted over a greater area and thus reduced the DDT concentration. Later tests have indicated that a certain proportion of motor oil is desirable, although 50 per cent is unnecessarily high.

In the test of February 23, in which the restriction plate was used, a 5 per cent solution gave good kills of insects over a swath of at least 250 yards. Control was complete at the end of the test lines and might have extended beyond this point. Because of the high wind and the altitude flown, first kills were observed 100 yards from the line of flight. In other tests control was obtained within 50 yards of the flight line. With the restriction plate and modified nozzle the linear distance covered by the spray was estimated at about twice that covered with the standard equipment.

The results of the test of February 25 emphasize the dependence of the treatment on wind velocity and direction, factors that cannot be controlled. In this test the effective swath was much narrower. With 5 per cent of DDT the restriction plate and the modified nozzle may distribute the spray too thinly for effective coverage.

In the two tests of March 1, 10 per cent of DDT gave better control than had been obtained with 5 per cent. With the more concentrated solution of DDT but shorter time of discharge, the amount of DDT per unit area was undoubtedly greater than in any of the earlier tests. In the second test on this date, which was flown at a higher altitude and under more favorable wind conditions than the first, the effective swath was probably wider than in previous tests. Unfortunately the test lines extended only 400 yards from the line of flight. Almost complete kill of houseflies was obtained from the 50-yard to the 400-yard station, and kills might have been obtained over a wider swath. Control of anopheline larvae in this second test was practically complete from a point under the plane to the end of the test lines, an indication that the spray would certainly have been effective well beyond this point.

When the restriction plate was used, the time of discharge with the simple nozzle was less than with the modified nozzle. The reason for this is not known.

The spray pattern was not uniform. This was particularly evident in those tests in which the deposit was observed on plates or filter paper. Because of this uneven coverage it is probably desirable to overdose so that a sufficient deposit will be obtained in all parts of the area.

CONCLUSIONS.—Good control of captive houseflies and anopheline mosquito larvae was obtained in preliminary tests by releasing DDT solutions from Chemical Warfare Service M-10 tanks attached to fast combat planes. Effective swaths under favorable conditions ranged from 150 to 400 yards. A plane flying cross wind and releasing one tank (27.5 gal.) of 5 per cent DDT solution under these test conditions would have given good control of insects over an area of about 30 acres, assuming a 200-yard effective swath and a linear coverage of 700 to 800 yards.

Better control of test insects was obtained with a 10 per cent solution of DDT than with a 5 per cent solution. It would seem desirable to use this higher concentration to compensate for the uneven character of the deposit obtained with this equipment, even though this may result in some overdosing. When applied at the dosage used in these tests, DDT may have injurious effects on fish, birds, frogs, and other wildlife. Such factors, however, would be of minimum importance in military operations.

These tests were the first to demonstrate the feasibility of controlling insects by release of DDT from fast combat aircraft. The equipment described was highly practical because of its immediate availability in all theaters of operation, although it was not the most suitable for the purpose. Its use stimulated further investigations in this field and served to fill the need until more efficient equipment had been designed.—10-1-45.

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# DDT as a Larvicide against *Simulium*[1]

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The investigations here reported were undertaken in an attempt to devise a practical method for the control or eradication of several species of *Simulium* (black flies or buffalo gnats) which are believed responsible for the transmission of a serious human filarial disease caused by *Onchocerca volvulus* in Guatemala and southern Mexico. The species of *Simulium* thought to be most important are *S. metallicum* Bellardi 1859 and *S. ochraceum* Walker 1860. The larvae of *S. callidum* Dyar & Shannon 1927, *S. mexicanum* Bellardi 1862 and *S. exiguum* Roubaud 1906 as well as several as yet unidentified species were also abundant in the streams where tests were made, but we were not able to study the differential responses to treatment of the different species, if any. Most of the work was done at or near the town of Yepocapa in the Department of Chimaltenango, Republic of Guatemala during October and November 1944 and April and May 1945, but a few tests were run in streams near Pochuta in the same department and in the Rio Michatoya which drains Lake Amatitlan in the Department of Guatemala.

For the purpose of orienting those who may be unfamiliar with *Simulium* a brief summary of the life history of these flies is here given.

The adult *Simulium* flies are diurnal, but generally attack most readily in shaded or partially shaded situations. They rarely enter dwellings. The maximum flight range is unknown, but scattered observations seem to indicate that it is considerable, in some cases exceeding five kilometers. The eggs are laid in swift streams on stones or trailing leaves covered by a thin film of water. Patches of eggs in favorable places may contain several thousand eggs, the results of the efforts of a number of females. The length of the egg stage of the Guatemalan species is not accurately known. The larvae attach themselves to stones, sticks and submerged or trailing vegetation by means of a circlet of hooks on the posterior end. These hooks are fastened into a patch of silk spun by the larva. Larvae move from place to place by spinning long threads on which they let themselves down to new locations, or by spinning new patches of silk and transferring the posterior hooklets to them by a series of looping movements. The length of larval life for the various Guatemalan species is not accurately known. Respiration in the larvae takes place both through the skin and by means of anal gills, both air in the form of fine bubbles and dissolved oxygen being utilized. Food consists of the microscopic plant and animal life caught in the basket-like mouth brushes which are held open by the current. Pupation takes place in shoe or slipper-shaped silken cocoons attached to rocks, leaves, etc., the open end of the cocoon being downstream and the pupa being held in place by hooks. Respiration during the pupal stage is accomplished by means of branched filamentous gills protruding from the anterior end of the pupa. The length of the pupal stage for the Guatemalan species is unknown.

The actual investigation may be divided into two phases, first, preliminary studies to determine whether DDT is capable of killing *Simulium* larvae under the conditions obtaining in the onchocercosis zone, and second, development of economically practicable methods of application.

The preliminary work was done with a concentrate consisting of 60 per cent xylene, 20 per cent DDT, and 20 per cent *Triton x-100* by weight. This concentrate, when diluted with 4 parts of water, gives a stable emulsion containing 4 per cent DDT. The first tests were made in wooden sluice boxes where the flow of water and hence the dilution of DDT could be accurately determined. Vegetation with *Simulium* larvae attached was placed in the boxes and the emulsion poured in

[1] This investigation was carried out under the auspices of the Pan-American Sanitary Bureau and formed part of a cooperative program with the governments of Guatemala and Mexico for the eradication of Onchocercosis. The senior author worked under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the Gorgas Memorial Laboratory, Panama, R. de P. Expenses were partially defrayed by a grant in aid from the Office of the Coordinator of Inter-American Affairs.

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**Table 1.—Trials of 4 per cent DDT emulsion in sluice boxes.**

| Box No. | Flow in Gals. Per Minute | Calculated ppm. | Estimated No. Larvae in Box | Larvae Attached At End of Treatment | Dead Larvae in Net | Pupae Collected | Pupae Emerged | Per Cent Emergence |
|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 7.8 | few | none | 8 | 58 | 11 | 6.38 |
| 2 | 300 | 2.6 | many | fair no. | 3[1] | 44 | 0 | 0 |
| 3 | 80 | 9.9 | 100 | none | 327 | 29 | 0 | 0 |
| 4 | 260 | 3.0 | few | none | 76 | 0 | — | — |
| 5 | 200 | 3.9 | 300 | 3, bottom box | 103 | 59 | 7 | 4.13 |
| 6 | 220 | 3.6 | 100 | none | not counted | 10 | 0 | 0 |

[1] Strong current probably washed most larvae through net.

slowly at the up-stream end of the box. A cloth net was placed over the lower end of the sluice box to catch detaching larvae. All larvae found in nets were dead or moribund within 2 hours after the treatment. Each treatment consisted in the application of approximately 750 cc. of the emulsion over a period of 10 minutes. Table 1 gives the results of this series of tests.

The pupae mentioned in the table were taken from the vegetation in the sluice box subsequent to treatment and held in individual emergence tubes for a least 3 days. Emergence under the same conditions of pupae from untreated streams varies widely but is generally at least 25 per cent. We feel that DDT kills a large proportion of pupae but is probably less effective against this stage than against the larvae.

It was next considered advisable to test the emulsion on a large scale and at greater dilutions. For this purpose a number of streams and small rivers were surveyed, their flow estimated and the presence of adequate numbers of *Simulium* larvae determined. They were then treated by pouring in over a period of an hour a quantity of emulsion sufficient to give the desired concentration of DDT. In some cases sluice boxes containing vegetation bearing *Simulium* larvae were placed in the streams some distance below the point of application, while in others certain leaves, branches or rocks bearing many larvae before treatment were marked and checked subsequent to treatment. Checking was usually done 24 hours after treatment, occasionally 48 hours later Table 2 summarizes the results obtained in this series of tests.

As can be seen from table 2, excellent results were obtained at very high dilutions. The last test is especially noteworthy, as 100 per cent kill was obtained at an initial concentration of only 1 part DDT in nearly 10 million parts of water.

Having established that the DDT emulsion will give satisfactory kills at very low concentrations, it was decided to try to see what effect treatment of all streams over a relatively large area would have on the adult population. This experiment was conducted by the junior author with the assistance of Dr. H. Elishawitz, and is being reported in detail separately, but will be summarized here for the sake of completeness.

An area of approximately 20 sq. km. containing three relatively large rivers and 27 smaller tributary streams, and lying well within the Onchocerca zone, was selected. An attempt was made to select an area having a high *Simulium* population and one that was as well isolated as possible by natural barriers from adjacent *Simulium*-infected territory. Treatment consisted of application to the area of the 60-20-20 xylene-*Triton*-DDT mixture diluted with water to give a 4 per cent emulsion, the dosage being calculated to give 0.1 ppm initial concentration. A satisfactory kill was obtained.

To check the adult populations, biting rates on human subjects at six stations in the treated area and three stations in an adjacent untreated area were taken over a period of 7 weeks. The results were not as clear cut as could have been wished, as the test was apparently made at the beginning of a natural seasonal decline in the adult population. Since little information was available as to the seasonal variations in *Simulium* abundance, this complication could not have been anticipated. The

**Table 2**

| Test No. | Quantity 4 Per Cent Emulsion in Gals. | Flow in Gals. Per Minute | DDT ppm. | Distance of Observed Kill in Meters | Remarks |
|---|---|---|---|---|---|
| 1[1] | 4 | 600 | 4.4 | 600 | Flow 800 gpm at 600 M. No increase for 900 M. |
| | | 1800 | 1.5 | 900 | Flow 5800 gpm at 1500 M. |
| 2 | 3 | 4000 | 0.5 | 2600 | Stream joined by another of 800 gpm flow at 2600 M. |
| | | 4800 | 0.41 | 3500 | No checking done beyond 6100 M. |
| 3 | 2 | 600 | 2.2 | 5740 | Sluice box placed 5740 M. below point of application. |
| | | 7000 | 0.18 | 5000 | Flow 7000 gpm at sluice box. Flow 15000 gpm at 10740 M. |
| 4 | 5 | 25000 | 0.13 | 10000 | 50% kill for an additional 1000 meters. Flow had increased to 40000 at 10 km. mark. |

[1] The first three tests are divided on the basis of increased flow. The total distance of kill from point of application is the sum of the two figures given.

decline in adult population was, however, greater and took place sooner in the treated area than the decline in the untreated area. Two other factors which may have played a role in maintaining the population in the treated area are the possibility of considerable infiltration of adults from adjacent untreated areas, since the maximum flight ranges of the species present is not known, and the possibility that enough very small seepage or spring-fed trickles were overlooked in the treatment to supply fair numbers of adults. Some support for the last supposition is given by the fact that reduction of *Simulium metallicum*, which breeds in fair sized streams, was relatively greater than reduction of *S. ochraceum*, which seems to prefer the smallest seepage streams.

Attention was next turned to the second phase of the investigation, the development of economically practicable methods of application. The use of drip cans was considered impractical, as very large numbers would be needed and it was felt that the cost would be too great and that they were unlikely to be satisfactory dispensers of an emulsion of this nature. The use of absorbent solids appeared to offer considerable promise, as it was felt that cakes or blocks would be a simple way of dispensing the DDT, doing away with the time factor in application, and making it relatively simple to train the cheapest labor to do the actual application. It was hoped also that it would be possible to find some method of prolonging the treatment to such an extent that the breeding streams could be "sterilized" as it were, for periods longer than the length of adult life. This, we believed, might reduce the number of treatments necessary for control to three or four, or possibly fewer per year.

Table 3 lists the various substances tried as absorbents and the results obtained. A number of the blocks gave quite satisfactory kills, but testing was hampered by the fact that one successful trial spoiled a whole stream for further testing for several weeks, and the number of accessible streams was rather limited.

The use of plaster of paris blocks, sponge gourds, or sacks of sawdust with solutions of DDT seem promising methods of application, especially for the smaller streams. Additional trials to find the best and cheapest combination should be initiated.

Since the cost of the xylene-*Triton*-DDT emulsion is relatively high, and all three ingredients must be imported, efforts were made to find substitute solvents and emulsifiers, especially substances obtainable in Guatemala. It was found that at room temperature (about 20° C) 100 cc. of commercial turpentine purchased locally would dissolve about 12 grams of DDT. In a letter from Dr. E. F. Knipling of the U. S. Dept. of Agriculture, dated January 4, 1945, he stated that his group has been able to dissolve about 14 per cent

Table 3

| No. | Form Applied | Composition | Where Applied | Conc.[3] ppm. | Gals. Per Min. | Results |
|---|---|---|---|---|---|---|
| 1. | Cast block | 25 g.pl. of paris<br>25 cc. stock<br>25 cc. water | small stream | 0.44 | 50 | Effective kill. Lasted a little over 24 hours. |
| 2. | Cast block | 25 g. plaster<br>25 g. DDT<br>35 cc. 5% *Triton X-100* in water | sluice box | 0.11 | 200 | 80% kill. Lasted less than 24 hours. |
| 3. | Cast block | 25 g. plaster<br>25 g. DDT<br>50 cc. water | sluice box | 0.11 | 200 | No apparent kill. Lasted a little over 24 hours. |
| 4. | Cast block | 50 g. plaster<br>50 cc. of a mixture of 25 cc. water, 50 cc. turpentine & 10 g. DDT | small stream | [1] | 100 | Effective kill. Lasted 48 hours. |
| 5. | Cast block | 50 g. plaster<br>35 cc. of a n ixture of 25 cc. water, 50 cc. turpentine & 6 g. DDT | sluice box | [1] | 200 | 90% kill. Lasted a little over 24 hours. |
| 6. | Cast block | 50 g. plaster<br>35 cc. of a mixture of 17.5 cc. water, 50 cc. turpentine & 6 g. DDT | sluice box | [1] | 200 | Effective kill. Lasted 24 hours. |
| 7. | Cast block | 50 g. plaster<br>30 cc. water<br>10 cc. sol. of 6 g. DDT in 50 cc. turpentine. | small stream | 0.04 | 100 | Effective kill. Lasted 4 days. |
| 8. | Cast block | 50 g. plaster<br>30 cc. water<br>15 cc. col. of 6 g. DDT in 50 cc. turpentine. | small stream | 0.12 | 50 | Effective kill. Lasted 3 days. |
| 9. | 12 oz. cans filled with various mixtures, plugged with plaster & with nail holes in sides and bottom. | 170 g. sawdust<br>200 cc. stock | stream | 0.18 | 1200 | Effective kill. Exhausted after 6 days when live larvae found on can. |
| 10. | " | 226 g. granulated charcoal<br>100 cc. stock[2] | stream | 0.14 | 800 | Not effective. Plaster plug dissolved after 24 hours. |
| 11. | " | 382 g. coarse salt<br>70 cc. stock[2] | stream | 0.019 | 4000 | 95% kill. Exhausted after 6 days and can half filled with sand. |
| 12. | " | 500 g. plaster<br>135 cc. stock[2] | stream | 0.5 | 300 | No kill after 24 hours and 60 hours. Plaster still intact. |

[1] Unable to calculate concentration because turpentine leaked out during setting of plaster.
[2] Stock referred to consisted of 25 per cent DDT, 7 per cent *Triton X-100*, 68 per cent xylene.
[3] Concentrations in all cases are included only for a basis of comparison and are calculated on a period of diffusion of one hour.

Table 3.—(Continued)

| No. | Form Applied | Composition | Where Applied | Conc.[3] ppm. | Gals. Per Min. | Results |
|---|---|---|---|---|---|---|
| 13. | " | 75 g. sawdust<br>50 g. plaster<br>200 cc. stock[2] | stream | 0.22 | 1000 | Effective kill 24 hours. About half contents dissolved. Can moved upstream 50 yds. No further kill after 5 days when can empty. |
| 14. | Plaster of paris blocks | 29 blocks 3×3×¾" which had absorbed 700 cc. of 4% DDT emulsion. | 5 small streams | 0.19 | 650 | Effective kill for 200 meters below last block in 5 hours. Previews treatment prevented further checking. |
| 15. | "Esparto" sponge gourds set with plaster | Sponge gourd set with plaster and allowed to absorb 350 cc. 4% DDT emulsion. | stream | 0.18 | 350 | Effective kill for 300 meters where stream joined large river. Plaster all washed out in 24 hours. |
| 16. | " | As above, but plaster set with 4% DDT emulsion instead of water. After drying absorbed more emulsion to a total of 650 cc. | large stream | 0.033 | 3500 | Effective kill for 1500 meters. Sponge placed at junction of stream used in test #15 with large stream. Plaster all washed out in 24 hours. |
| 17. | Sawdust in cloth sack. | 0.8 gal. 25% DDT, 7% *Triton*, 68% xylene absorbed by sufficient sawdust to give a moist mix. | river | 0.13 | 25000 | Perfect kill for 6 km. in 48 hours. No kill at 11 kms. Sack moved upstream 50 yds. and checked several days later but no further kill. |

DDT in turpentine at 27°–30° C and up to 25 per cent by warming, which agrees fairly closely with our results. Although xylene will dissolve about 4.5 times as much DDT as turpentine, it cost nearly 7 times as much in Guatemala. It would, therefore be possible to effect a considerable saving in materials cost to use turpentine in place of xylene in making up the concentrate.

The berries of the tree *Sapindus saponaria* are used locally for washing clothes and contain a relatively high proportion of saponin. A crude alcoholic extract of these berries was tried as an emulsifying agent. By its use a good emulsion of turpentine and water was formed which, however, was stable for only a short time, separating into two distinct layers in about an hour. Its homogeneity could be immediately restored by shaking. There is a possibility that crude saponin extracted from these berries could be used as an emulsifying agent, although methods of extraction and costs would have to be worked out, as well as the best proportions to use.

During the course of the tests with turpentine, a single field test was made using turpentine as a solvent, but without an emulsifying agent. Ninety-five grams of DDT were dissolved in 950 cc. of turpentine, and to this was added 2835 cc. of kerosene, to make one gallon. The kerosene was added to make bulk, since the solution had to be poured into a stream during a period of an hour, and the larger volume of liquid could be more evenly poured. A stream with an estimated flow of 4000 gals per minute, and having an adequate larval population, was selected and the kerosene-turpentine-DDT solution poured in throughout a period of 1 hour. This gives a concentration of approximately 1 part DDT to 10 million parts of water. The turpentine

and kerosene could be seen as a thin oily film on the water for some distance downstream. Checking the following day showed but two living larvae over a distance of 2580 meters. These two larvae were at 1500 meters, not far from the junction of a small side stream. No larvae were found in the sluice box 2100 meters from the point of application.

Since neither turpentine nor kerosene is miscible with water and no emulsifying agent was used, we believe that the results observed in this test were due to actual solution of the DDT in water. DDT is said to be soluble in 10 to 15 million parts of water.

To test further the possibility that enough DDT can be dissolved in water to give practical kills, an additional test was run. To 226 grams dry DDT was added 100 cc. *Triton* and the two were mixed to a smooth paste. Water was added gradually to form about a gallon of suspension and the whole was poured gradually, with frequent stirring and shaking, into a river estimated to have a flow of about 8500 gals. per minute. This dosage applied through a period of an hour, gives a concentration of about 1 in 10 million. Larvae of *Simulium* were very scarce immediately below the point of application but at a distance of 2 kilometers downstream were fairly abundant. After treatment no larvae could be found for a distance of approximately 4 kilometers from the point of application. We believe that soap or saponin or any other wetting agent could have equally well been substituted for the *Triton* in this case.

With the demonstration that DDT in the form of very dilute suspensions will give effectual kill the problem of methods of application changes. The search for cheaper and more effective solvents and emulsifiers becomes unnecessary and attention may be directed towards dispensing methods suitable for use by relatively untrained personnel. The following possibilities suggest themselves: (1) a powdered or fine granular combination of DDT and soap; (2) a paste of soft soap and DDT to be mixed with water at the time of application; (3) bars of quickly soluble soap containing DDT to be placed in the smallest streams and seepages.

SUMMARY.—Tests of DDT as a larvicide to control *Simulium* breeding in swift flowing mountain streams in Guatemala are reported.

Using an emulsion containing 4 per cent DDT made from a stock concentrate containing 20 per cent DDT, 20 per cent *Triton X-100* and 60 per cent xylene, complete eradication of *Simulium* larvae from streams for distances up to 10 kilometers was effected at concentrations of 1 part DDT to 10 million parts water.

Efforts to prolong larvicidal action by absorbing emulsions and solutions of DDT on porous substances were unsuccessful. However, solutions of DDT absorbed by porous substances offer possibilities as a method of application for treatment of small streams.

Trials of turpentine and crude saponin from soap berries indicate that they are moderately effective as solvent and emulsifying agent respectively, and might economically replace xylene and *Triton* in Guatemala.

Further tests show that DDT powder made into a suspension in water with a wetting agent gave kills as satisfactory as those obtained with emulsions.[1]—1-10-46.

[1] Printing costs paid by the Gorgas Memorial Laboratory to secure early publication.

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## FOURTH ANNUAL CANADIAN PEST CONTROL OPERATORS CONFERENCE

The Fourth Annual Conference of the Canadian Pest Control Operators will be held in the Hotel Windsor, Montreal, on February 18, 19 and 20. The business meeting is scheduled for the 18th. Research projects, demonstrations, discussions of the place to be played by some of the new insecticides in the practical pest control program and other timely topics will constitute the main attraction which should be sufficient to attract a large attendance.

# DDT as a Chicken Louse Control

HORACE S. TELFORD,[1] *Ashland, Ohio*

Preliminary investigations with DDT louse powders on chickens (Telford 1944, 1945) showed this insecticide to be toxic to the body louse, *Eomencanthus stramineus* (Nitzsch), the shaft louse, *Menopon gallinae* (L.), and the fluff louse, *Goniocotes hologaster* Nitzsch in concentrations from 0.5 to 4.0 per cent and to exhibit excellent residual properties. Warren (1945) concluded that "DDT in concentrations up to 10 per cent · · · does not afford the chicken any better protection than is provided by the standard sodium fluoride." The observations herein recorded, conducted during the summer and early fall of 1944, describe further experiments on the use of DDT as sprays, dips, dusts, and oral dosages against these same species of lice. Emphasis is placed on methods of flock treatment to eliminate the handling of individual birds.

METHODS AND MATERIALS.—The chickens under trial were from a commercial flock of White Leghorn hens. With few exceptions all harbored light to gross infestations of one or more species of lice. Miscellaneous equipment included: poultry houses, laying batteries of individual cages for confining the birds during certain spraying trials, a hand-operated *Lowell* cattle fly-sprayer for spraying individual birds; a *Dobbins* (*No. 133*) hand-operated dust gun, and a 2.5 gallon *Myers* (*No. 2240*) hand-operated pressure sprayer for applying dusts and sprays to flocks and to the interiors of poultry houses; a dim flashlight for use when flocks were sprayed while roosting at night.

To determine the efficacy of treating individual birds, whether by oral dosing, dipping or spraying, the technique employed was identical with that previously described (Telford 1945). Where entire flocks were treated simultaneously, both large (33 to 90 birds) and small (4 to 10 birds) size flocks were employed. In experiments with large flocks the efficiency of the treatment was determined by examination of 20 birds selected from the treated group. An adjoining poultry house confining a similar number of birds served as controls. The small flock tests were controlled by examination of 6 untreated marked birds maintained in an infested flock.

EXPERIMENTAL RESULTS.—*Oral Dosages of DDT.*—The possibility of oral dosages being effective was suggested in the work of Lindquist *et al.* (1944), in which they obtained kills of bedbugs by allowing them to feed upon experimental rabbits that had been given oral dosages of DDT. Bedbugs are ideal test animals for such experiments, since they are susceptible to DDT and feed by sucking blood, thus readily taking up any chemicals which may be absorbed by the blood. While one could hardly expect efficient control of chicken lice by this method, nevertheless they are very susceptible to DDT and though primarily chewing insects, the work of Wilson (1933) indicates that the body louse may feed upon blood taken from the punctured soft quills near the base of the feathers.

Four chickens harboring light to gross infestations of body and shaft lice were given one gram each of DDT in gelatin capsules and placed in laying batteries. These birds exhibited no toxic symptoms, remained on feed and laid some eggs while under observation. Examinations were made 3 hours, 24 hours, 6 days and 13 days after administration. At 13 days no appreciable change in the population of body lice and shaft lice occurred in either the treated birds or the 4 birds serving as controls. The average weights of the treated and control birds at the beginning of the experiment were 2333 and 2250 grams respectively. Four days later the treated birds had lost an average of 83 grams per bird. The control birds lost 22 grams.

TREATMENT WITH DIPS.—Four birds with light to gross infestations of shaft and body lice were dipped in a DDT 0.03 per cent emulsion containing:

| | |
|---|---|
| DDT | 2.4 grams |
| Deodorized kerosene | 30.0 grams |
| *Vatsol OT*[2] | 16.0 grams |
| water to make | 8000 cc. |

Almost complete kill was achieved within 4 hours. No live lice were found in 2 sub-

[1] Entomologist, Dr. Hess & Clark, Inc.

[2] *Vatsol OT* is a dioctyl ester of sodium sulfo succinate.

sequent examinations 2 and 3 days later. These birds were then banded for later identification and released into an infested flock of approximately 100 birds. Forty-four days after treatment, all birds were free of lice except one which harbored 5 shaft lice. This infested bird died of extraneous causes before the next observation, 67 days after treatment. At this time one of the remaining birds harbored a light infestation of shaft and body lice; the second, 5 body lice; and the third was still free of lice.

To determine whether the solvent or the wetting agent may have accounted for these louse reductions, these materials were tested separately on three groups of four birds each, using the following formulations: (1) deodorized kerosene 30 grams, *Vatsol OT* 16 grams, in 8 liters of water; (2) *Vatsol OT* 16 grams, in 8 liters of water; and (3) heavy mineral oil 30 grams, *Vatsol OT* 16 grams, in 8 liters of water. Considerable reduction of body and shaft lice occurred in every trial; however, infestations began building up within 3 days after treatment, and when the birds were released into the infested flock and reexamined in 67 days, they harbored infestations comparable to their original louse populations. No appreciable change took place in the louse populations of 6 untreated control birds also maintained in an infested flock.

TREATMENT WITH SPRAYS.—As a preliminary step to determine the practicability of flock spraying, 5 trials of 4 birds each were conducted by spraying individual birds placed in laying batteries. A summary of the essential data is included in table 1. The sodium fluoride sprays, 0.7 per cent, were ineffective at 31.1 cc. and 32.2 cc. per bird. The DDT 2.5 per cent emulsions at 32.8 cc. to 39.1 cc. per bird were highly effective. The residual effects of the DDT sprays were not as lasting as the dips containing this insecticide. All sprayed birds introduced into an infested flock were free of lice up to 15 to 19 days, but after 33 to 37 days incipient infestations of shaft and body lice appeared. The louse populations of the birds sprayed with sodium fluoride, and the 6 control birds both maintained in an infested flock, remained relatively constant up to 37 days.

SPRAYING AND DUSTING FLOCKS AND HEN HOUSES.—Results in applying DDT compositions to individual birds as dusts (Telford 1945), dips and sprays were sufficiently successful to warrant trials of flock treatment by these materials. Three types of investigations were undertaken, they were: (1) flock spraying, (2) spraying hen houses, and (3) dusting flocks and hen houses

Seven sprays of known DDT compositions were applied to 5 large and 2 small flocks after the chickens had gone to roost. A summary of the essential data is shown in table 2. In the DDT 2.5 and 5 per cent concentrations, shaft and fluff lice were effectively controlled; but the weaker emulsion was ineffective against body lice. The greater resistance of this species is due probably to its habit of feeding on the bird's skin; the other 2 species are usually more exposed because they feed on the feather shafts, barbs and barbules. There was no interruption in egg production or discoloration of the feathers following administration, and the birds showed no discomfort from the treatment. From the standpoint of economy of materials and satisfactory kills, a DDT 5 per cent emulsion or suspension applied at the rate of 22 to 54 cc. per bird is most promising. Perhaps further ex-

**Table 1.—Results of spraying individual birds in laying batteries.**

| Trial No. | Formula | Cc. per Bird | Number of Birds | Observation Period | Species of Louse: Body | Shaft | Fluff | Residual[2] Effect | Effect of Treatment on Lice |
|---|---|---|---|---|---|---|---|---|---|
| 1 | DDT 2.5%, benzol 10%, *Vatsol OS*[1] 0.5% in water | 32.8 | 4 | 49 days | x | x | x | Yes | Complete kill within 40 hrs. |
| 2 | Same formula | 34.7 | 4 | 53 days | x | x | x | Yes | Complete kill within 48 hrs. |
| 3 | Same formula | 39.1 | 4 | 51 days | x | x | x | Yes | Complete kill within 48 hrs. |
| 4 | Sodium fluoride 0.7% in water | 31.1 | 4 | 37 days | x | x | | — | No control |
| 5 | Sodium fluoride 0.7%, *Vatsol OS* 0.5% in water | 32.2 | 4 | 37 days | x | x | | — | No control |

[1] *Vatsol OS* is a sodium salt of an alkyl naphthalene sulfonic acid.

[2] A preparation which destroys all lice on a treated bird and which prevents reinfestation for 5 to 7 days exhibits, for purposes of this paper, a "residual effect" regardless of whether that effect is ovicidal or by a residue of active insecticide that remains in the feathers and destroys newly hatched lice as they emerge.

**Table 2.—Results of flock spraying experiments.**

| Trial No. | Formula | Cc. per Bird | Number of Birds | Observation Period | Species of Louse: Body | Shaft | Fluff | Residual Effect | Effect of Treatment on Lice |
|---|---|---|---|---|---|---|---|---|---|
| 1 | DDT 2.5%, benzol 3.7% *Vatsol OS* 0.2% in water | 36 | 90 | 28 days | | x | | Yes | Complete control within 36 hrs. |
| 2 | Same formula | 47 | 6 | 6 days | x | | | ? | Complete control of shaft lice, approximately 50% control body lice within 6 days. |
| 3 | DDT 5%, benzol 10%, *Triton X-100*[1] 0.3% in water | 54 | 55 | 21 days | x | x | | Yes | Complete control within 7 days. |
| 4 | DDT 2%, *Pyrax* 4%, bentonite 2% in water | 280 | 8 | 4 days | x | x | x | Yes | Shaft and fluff lice killed within 40 hrs., body lice within 4 days. |
| 5 | DDT 5% *Deenol* water suspension | 30 | 45 | 30 days | x | x | x | Yes | Complete control within 3 days. |
| 6 | Same formula | 22 | 41 | 30 days | x | x | x | Yes | Complete control within 3 days. |
| 7 | Same formula | 32 | 43 | 30 days | x | x | x | Yes | Complete control within 3 days. |

[1] *Triton X-100* is polyethylene glycol monoisooctyl phenyl ether.

perimentation would result in effective control at lower dosages of the 5 per cent concentration.

Tests were conducted with various DDT sprays and dusts to determine if control could be achieved by applying the insecticide only to roosts, floors and nests. Sprays consisted of DDT, 2.5 and 5 per cent emulsions, and dusts contained DDT, 2 and 5 per cent in *Pyrax*. Two large and 6 small flocks were under observation. A summary of the results on dusting and spraying is embodied in table 3. DDT sprays, 2 to 2.5 per cent, on floors, roosts and nests in sufficient quantities hold some promise for control of lice, but they are slow to kill since complete control was not realized until 26 days after application. Better results might have been recorded for Trial No. 4 had observations been continued for a longer period of time.

The DDT dusts, 2 and 5 per cent, were generally unsatisfactory. One trial out of 4 gave complete control 5 weeks after application.

SUMMARY AND CONCLUSIONS.—One gram of DDT was administered orally to each of 4 louse-infested birds averaging 2333 grams. No significant reduction of body lice or shaft lice resulted.

Dipping 4 birds grossly infested with body and shaft lice in a DDT 0.03 per cent emulsion gave almost complete control in 4 hours. Complete control was achieved within 2 days. These birds were then placed in an infested flock of 100

**Table 3.—Results of hen house spraying and dusting experiments.**

| Trial No. | Formula | Amount per Sq. Ft. | Number of Birds | Observation Period | Species of Louse: Body | Shaft | Fluff | Residual Effect | Effect of Treatment on Lice |
|---|---|---|---|---|---|---|---|---|---|
| 1 | DDT 2.5%, benzol 3.7%, *Vatsol OS* 0.2% in water (spray) | 6.6 cc. | 90 | 28 days | | x | | Yes | Within 72 hrs. 16 of 20 birds examined were free of lice. Within 10 days all birds free. |
| 2 | Same formula (spray) | 6.3 cc. | 6 | 26 days | x | x | x | Yes | All free of lice within 26 days. Body lice last to be killed. |
| 3 | DDT 2.5%, benzol 5%, *Vatsol OS* 0.5% in water (spray) | 20.0 cc. | 6 | 26 days | x | x | | Yes | Complete control of shaft lice in 6 days. Body lice at 26 days. |
| 4 | DDT 2%, *Pyrax* 4%, bentonite 2% in water (spray) | 6.3 cc. | 6 | 12 days | x | x | x | — | Partial control of all species |
| 5 | DDT 2% in *Pyrax* (dust) | 1.4 gr. | 6 | 5 weeks | x | x | x | — | Twelve body lice on 1 bird remaining at 14 days. |
| 6 | DDT 2% in *Pyrax* (dust) | 0.8 gr. | 10 | 46 days | x | x | x | — | Shaft and fluff lice killed in 7 days. Three birds still infested with body lice at 46 days. |
| 7 | DDT 5% in *Pyrax* (dust) | 0.8 gr. | 10 | 30 days | x | x | x | — | Shaft and fluff lice killed in 7 days. Two birds still infested with body lice at 30 days. |
| 8 | DDT 2% in *Pyrax* (dust) | 3.9 gr. | 90 | 32 days | x | x | x | — | Shaft and fluff lice killed in 21 days. Six of 20 birds examined still infested with body lice at 32 days. |

birds. On the forty-fourth day one bird, which died soon after examination, harbored 7 shaft lice. The surviving 3 were free of lice. In 67 days one was still free of lice, one harbored 5 body lice and one harbored incipient infestations of body and shaft lice. Dipping 12 infested birds in low concentrations of wetting agents both with and without solvents gave poor control of body and shaft lice.

Spraying 12 birds individually in laying batteries with DDT, 2.5 per cent emulsion at the rate of 32.8 to 39.1 cc. per bird resulted in complete control of body, shaft and fluff lice within 40 to 48 hours. These birds released into an infested flock were free of lice up to 15 and 19 days, but after 33 to 37 days incipient infestations of body and shaft lice appeared. Sodium fluoride 0.7 per cent individually sprayed on 8 birds at the rate of 31.1 to 32.2 cc. per bird gave no control of body and shaft lice.

In 6 flock spraying trials using 2 to 5 per cent DDT emulsions and suspensions applied at the rate of 22 to 280 cc. per bird controlled all three species of lice from 36 hours to 7 days. One trial using a 2.5 per cent DDT emulsion applied at the rate of 47 cc. per bird failed to control body lice at the end of 6 days.

Spraying floors, roosts and nests in hen houses with a DDT, 2.5 per cent emulsion, 6.3 to 20 cc. per sq. ft., gave complete control within 26 days. In one trial, a DDT 2 per cent suspension, sprayed at the rate of 6.3 cc. per sq. ft. gave partial control in 12 days. DDT dusts from 2 to 5 per cent, applied on the floors, roosts and nests at the rate of 0.8 to 3.9 grams per sq. ft., were generally unsatisfactory against body, shaft and fluff lice since only one trial out of 4 gave complete control. Shaft and fluff lice were more easily controlled by spraying and dusting than body lice.

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# Leaf Area and Its Relation to Application of Insecticides

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Directions as to the amount of material to use for the application of insecticides to crop plants are given for sprays in terms of dilution and for dusts in terms of pounds per acre of ground or merely a statement to use a certain dilution. Such directions convey very little specific information since it is obvious that the amount of the spray or dust to use depends on the plant surface to be covered with the insecticide and not the ground area.

If the amount of insecticide required to control leaf-eating insects and the leaf area are known, then it is possible to estimate how much poison must be deposited per unit of area for proper control. However, when attempting to translate this information to field conditions it was found that the leaf area of growing plants was not generally known, and no data were available. Since the importance of the leaf area of growing plants to insecticide and fungicide applications and other related factors was realized, data were secured on the leaf area of bunch bean and burley tobacco plants during their period of growth in the field. These plants were selected because of their different configurations, also both are commonly treated with insecticides.

METHODS OF SECURING DATA ON LEAF AREA.—Seeds of Stringless Green Pod beans were planted on June 3, at the rate of 90 pounds per acre in eight rows 2.5 feet wide and 65 feet long. The stand obtained averaged plants 2.93 inches apart or at the rate of 71,438 plants per acre. Previous to planting, a heavy crop of crimson clover was plowed under. On

Table 1.—Summary of data on leaf area of growing bunch bean and burley tobacco plants.

| Date | | Number Leaves Per Plant | | Leaf Area in Sq. Cm. Per Plant | | Leaf Area in Acres of Foliage Per Acre of Ground | |
|---|---|---|---|---|---|---|---|
| Bean | Tobacco | Bean[1] | Tobacco | Bean | Tobacco | Bean[2] | Tobacco[3] |
| June 17 | July 5 | 2.0 | 11.1 | 101.1 | 2,620 | .18 | .65 |
| June 22 | July 14 | 4.0 | 14.9 | 270.7 | 6,894 | .49 | 1.70 |
| June 29 | July 20 | 9.6 | 18.0 | 683.8 | 9,086 | 1.20 | 2.25 |
| July 7 | July 27 | 14.2 | 19.4 | 1764.0 | 13,444 | 3.07 | 3.33 |
| July 14 | Aug. 4 | 21.4 | 21.3 | 3058.0 | 17,746 | 5.34 | 4.39 |
| July 21 | Aug. 11 | 23.4 | 21.9 | 3015.0 | 21,072 | 5.42 | 5.20 |
| July 28 | Aug. 18 | 22.1 | 21.1 | 2598.0 | 20,886 | 4.51 | 5.16 |
| Aug. 4 | Aug. 25 | 22.5 | 21.0 | 2110.0 | 20,254 | 3.67 | 5.00 |
| | Sept. 1 | | 18.6 | | 18,322 | | 4.52 |

[1] Composite leaves.
[2] Only one side and 70,356 plants per acre.
[3] Only one side and 10,000 plants per acre.

July 1 a side dressing of sodium nitrate was applied to the beans at the rate of 150 pounds per acre. The plants at all times appeared normal.

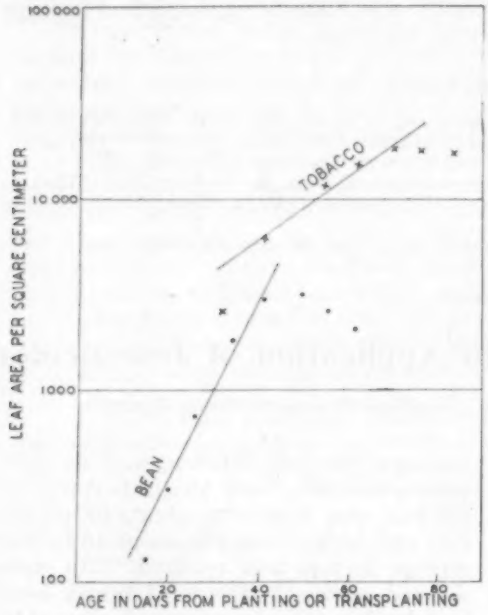


FIG. 1.—Leaf area on beans and tobacco.

Beginning on June 17 and at weekly intervals for the next seven weeks, the total leaf area of 8 bean plants was recorded. One plant was selected in each row where the stand was uniform and the plants were evenly distributed. The measurements were made by placing each leaf under a transparent piece of lucite which was marked off in squares of .04 sq. cm.

On June 2 plants of burley tobacco were set out in a 10-row plot with rows 3 feet wide and 65 feet long. On July 5 and at weekly intervals the leaf area of 10 plants was recorded. The stand was uniform at about the rate of 10,000 plants per acre, and the plants to be measured were selected in the same manner as the bean plants. A crop of crimson clover was plowed under shortly before transplanting, and triple phosphate was applied in the row at rate of 300 pounds per acre when transplanting was done. The measurements were made by placing a large piece of celluloid, marked off in 1-inch squares, over each leaf and recording the number of square inches in each leaf.

DATA OBTAINED.—The area of bean foliage per plant increased from 101.1 sq. cm. on June 17 to 3058 sq. cm. (3.30 sq. ft.) on July 14. The plants maintained practically the same maximum area for the period between July 14 and July 21. After July 21 the area showed a definite decrease as the older leaves died and fell.

The data for bean plants are shown in table 1 and figure 1. Following the method of Brody (1927) it was found that the leaf area of beans increased at the instantaneous percentage rate of 12.7 per cent, and at this rate the leaf area on the plants was doubled every 5.47 days beween June 3 and July 14.

On July 5 the burley tobacco plants each had from 10 to 14 leaves, with an average of 2620 sq. cm. (2.82 sq. ft.) per plant. In 37 days (August 11) the plants had reached their maximum in total leaf area, an average per plant of 21,072 sq. cm. (22.68 sq. ft.). For the dates of August 11, 18 and 25 the total was about the same, ranging from 21,072 sq. cm. to 20,254 sq. cm. By September 1 the area had definitely decreased, as the lower

Table 2.—Leaf area of burley tobacco plants at harvest time. Greeneville, Tennessee, August 24.

| Variety | Total Square Feet of Leaf Area for Plant | | | | | Aver. No. of Sq. Ft. per Plant | Aver. No. Leaves per Plant | Sq. Ft. per Leaf | Acres of Leaf Surface per Acre of Ground Surface |
|---|---|---|---|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | | | | |
| Station No. 8 | 15.23 | 23.81 | 16.99 | 23.58 | 23.48 | 21.22 | 16.2 | 1.31 | 4.87 |
| Kelley | 16.17 | 15.17 | 23.06 | 14.81 | 20.56 | 17.94 | 13.8 | 1.30 | 4.11 |
| Kentucky 16 | 19.50 | 16.21 | 19.96 | 27.72 | 22.24 | 21.12 | 15.2 | 1.39 | 4.84 |
| Judy's Pride | 18.55 | 11.92 | 18.98 | 16.60 | 21.64 | 17.54 | 14.0 | 1.25 | 4.02 |
| Harrow Velvet | 23.15 | 18.12 | 25.51 | 17.10 | 18.46 | 20.47 | 19.6 | 1.04 | 4.70 |

leaves had dried and fallen. The plants were ready for harvesting during the week between August 18 and 25.

The data for tobacco plants are shown in table 1 and figure 1, in comparison with the data on bean plants.

It was found that the tobacco grew at instantaneous percentage rate of 6.7 per cent and doubled its area every 10.2 days. This is about one-half the rate of the beans.

On August 24 at the Tobacco Experiment Station, Greeneville, Tennessee, five plants of five different burley varieties were measured at cutting time. It was found that the leaf area per plant varied from 17.54 sq. ft. to 21.22 sq. ft. (Table 2). This is fairly close to the leaf area recorded at Knoxville on an unknown variety of burley (Table 1).

Spray Deposits on Bean Plants.—The beans used to obtain the leaf area were used also in experiments to control the Mexican bean beetle. Two applications of insecticide were made on the following dates: June 27 and July 11. The doses varied from 1.5 pounds to 6 pounds per 50 gallons of water and were sprayed on the foliage at the rate of 200 gallons of water per acre of ground acreage. The sprayed leaf surface varied from 2.2 acres, on June 27, to 10.2 acres, on July 11 per acre of ground. Thus in 14 days the leaf area increased five times, while the amount of insecticide used remained the same. Since the amount of poison applied per unit of leaf area was calculated on the basis that all the material sticks to one side of the leaves, the dosage of 1.5 pounds per 50 gallons gives a deposit of .030 mg. per sq. cm. of leaf surface on 2.2 acres and only .007 mg. on 10.2 acres. The dosage of 6 pounds varies from .121 mg. to .025 mg. for the same acreage.

In M.L.D. studies (unpublished data) using synthetic cryolite, a deposit ranging from .111 mg. to .210 mg. of cryolite per sq. cm. of leaf surface was required for a 50 per cent kill of Mexican bean beetle larvae. The deposits of .111 mg. and .210 mg. per sq. cm. range from about 10 pounds to 20 pounds per acre (43,560 sq. ft.). Data on field tests have shown that larger amounts are more effective.

Summary.—The rapid increase in leaf area of growing bunch beans and burley tobacco was measured and it was found that the leaf area of beans increased much faster than that of tobacco. It was calculated that the beans grew at an average daily rate of 12.67 per cent and the tobacco at 6.77 per cent. The bean plants averaged a maximum of 3058 sq. cm. (3.30 sq. ft.) per plant and the tobacco 21,072 sq. cm. (22.68 sq. ft.). However, on an acre basis the total leaf area was about the same, slightly over 5 acres, for both crops.

Most instructions on how to apply insecticides to plants give statements in terms of pounds of insecticide per acre of ground. Since the information obtained shows that the area of the leaves to be treated may be 5 to 10 times[1] more than the ground acreage, the instructions should consider also the stage of the development of the plants—the plant-surface area per acre of ground.

M.L.D. studies show that an insecticide in field use must be applied in doses approaching those used in laboratories for effective results.—11-20-45.

[1] In the spraying of beans much of the spray settles on both sides of the leaves. Area of stalks and stems was not considered in the study.

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# SCIENTIFIC NOTES

## *Platypus compositus* Attacking Citrus

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The ambrosia beetle *Platypus compositus* Say is common in the Southern states. Blackman reported that in Mississippi he took it from hickory, pecan, yellow birch, cottonwood, weeping willow, sweet gum, sour gum, magnolia, and red oak (Blackman 1920). It has also been reported from black oak, sugar maple, chestnut, basswood, red elm, beech and wild cherry (Hopkins 1893). The author has received two groups of specimens from Florida areas where it is attacking citrus trees. Identification was made by W. H. Anderson. Specimens were taken in a seedling grove near Wachula where it was doing quite a bit of damage. J. P. Linduska, of the Bureau of Entomology and Plant Quarantine of The United States Department of Agriculture forwarded specimens collected in the Lakeland area. These were attacking orange trees. The infestation was spotty but severe on those trees attacked. Injury was on the branches as well as on the trunk. These attacks seem to have followed a prolonged rainy period.—12-28-45.

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## The Alleghany Mound Ant and Its Control

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For many years the Alleghany Mound Ant, *Formica exsectoides* Forel, has been known on sandy slopes of mountains in Pennsylvania. McCook in 1877 made some observations on the mounds, life history and behavior of their pest.[1] In 1928, several hills belonging to this species of ant were located on a farm near Louisville, Kentucky. At that time, the then usual recommendations for the destruction of ant nests were furnished to the land owner. In 1943, the ants were found on about 30 farms in the Louisville area and the farmers reported little or no success in controlling the pests with the remedies suggested. A survey of the premises showed that the mounds appeared at the rate of about 18 per acre, with the number increasing rather rapidly as indicated by the recently established ones. In one instance the hills had spread to the yard and to a point 15 feet from the house.

The mounds built by these ants varied in size. The largest one found was 3 feet high and 6 feet in diameter. The older and larger ones were covered with a thin blanket of litter made primarily of finely broken or ground pieces of stems, leaves and bits of straw, inter-mingled with fresh pellets of earth. The main open burrows were near the bases of the mounds, and it appeared that the ants coming to and leaving the hills used these openings, though there were openings over the entire peripheries of the mounds where pellets of earth were being brought up from inside and deposited.

In the general area of the mounds, the ground was practically covered with running ants. They were a nuisance and a source of great discomfort on account of their painful bites. These they execute by bruising and scraping the skin with the mandibles and then spraying the affected area with an acid secretion.

In an effort to discover a practical remedy several different insecticides were tested in the laboratory. After many trials it was found that a solution of a 2% pyrethrum stock[2] diluted at the rate of 2 ounces to 10 gallons of water killed all ants coming into contact with the liquid and when poured onto the open mound completely exterminated the entire nest within a few seconds after treatment.

The procedure for treating a mound is simple. With a hoe the top of the mound is pulled down to form a crater, the inside diameter of which approximates the base of the hill. This opens up the tunnels for the ready entrance of the liquid and at the same time prevents run-off of the insecticide when it is poured rapidly into the crater. If the mound is not more than 5 or 6 inches high, formation of a crater is not necessary. The insecticide can be poured over the mound without having disturbed it. As soon as the crater has been formed (in case of the large mounds) the insecticide which has been prepared previously by adding the pyrethrum stock to the water and stirring in a milk can or other wide-mouthed receptacle, is poured. The liquid rapidly disappears down the tunnels leaving the openings sealed with mud, resulting in a perfect kill.

For mounds 2½ feet in diameter 10 gallons of the anticide will be necessary. If the hills to be treated are larger or smaller a proportionate amount should be used. Incidentally this treatment is excellent for the control of species of ants found around the yard and garden, two or three quarts of the material being sufficient for a single mound.

After treating one of these mounds, which before cratering, stood about 18 inches above the ground level, it was excavated. The soil was a very light sandy loam which made handling easy. A trench 20 inches wide and 6½ feet deep was dug around the hill, leaving a core in the center 5 feet in diameter. The core was then pared down by removing layers apprpximately 2 inches in thickness. It was found that the shape of the nest below ground was that of an inverted cone about 3 feet in diameter at the top and extending into the ground 5½ feet. The interior was permeated with smooth-lined tunnels about ¾ inch in diameter.

The ants, killed in situ, were found in dense spots throughout the nest. The greatest concentration, however, was in the upper part of the cone from 10 to 24 inches below the ground level. Multiple queens were found in the mound and it appeared probable that the densely populated areas in the tunnels were the scenes of brood-rearing activities.

The excavation of the mound disclosed that the remedy was highly effective and gave immediate results. It had the additional advantage of being easy of application without causing injury to the grass.—12-11-45.

[1] Trans. Am. Ent. Soc. 6: 253.

[2] The stock used was Red Arrow containing pyrethrins 2.0 per cent and vegetable oil soap 33.0 per cent.

## Two Squash Root Aphids

GEORGE F. KNOWLTON, *Utah State Agricultural College, Logan*

Two species of aphids, *Trifidaphis phaseoli* (Passerini) and *Aphis middletonii* Thomas (det. M. A. Palmer) were extremely abundant and were destroying young squash plants in a commercial field at Roosevelt, Utah, on July 18, 1941. The aphids were being attended by large numbers of ants, *Lasius niger* var. *neoniger* Emery (det. A. C. Cole). Both species of aphids were present on the roots of all squash plants examined.

In a 10-acre field of squash examined by Mr. H. F. Thornley and the writer, approximately 3 acres to the east were separated from the rest of the field by a small irrigation ditch. In this part of the field fully 50 per cent of the squash plants already were dead; many others died subsequently. In the remaining 7 acres some spots were less severely affected by the aphids. However, more than 30 per cent of the plants in the south portion of the field, and approximately 20 per cent of the plants to the north had been destroyed by these aphids. Many small plants appeared to be stunted or in such poor condition that their survival was extremely doubtful.

*Trifidaphis phaseoli* specimens on squash were of a dirty whitish color, smudgy pearl-like in appearance. This color was lighter than that of specimens collected on roots of beans, which were more olive-green to brownish.—11-10-45.

## Elateridae Eaten by Utah Birds

GEORGE F. KNOWLTON, *Utah Agricultural Experiment Station, Logan*

A reading of Thomas,[1] two discussions of birds as predators on Elateridae led the writer to summarize the following data from examination records of bird stomach contents from the studies made during the past eleven years. Most of these birds were collected in Utah during late summer and fall; approximately 75 per cent of the stomachs were from birds taken on range land and the rest in crop areas. This may account for the elaterid count being lower than that found by several investigators for stomachs of birds collected in spring. During the spring, adult click beetles apparently are more abundant above ground, wireworms are nearer the surface, and at that time many insectivorous birds have been found to pick up large numbers of wireworms and other soil insects in plowed and cultivated fields, many such insects being fed to nestling young. A similar condition probably exists in Utah cultivated areas during the spring.

Table 1 indicates the 29 species of birds in one or more of whose stomachs Elateridae were found. A total of 108 adult click-beetles are recorded. The presence or absence of elaterids in collected stomachs would largely reflect the availability and abundance of these forms at the time and place each bird had fed shortly before it was collected.

Ten wireworms were recognized among the insect food, 2 being found in stomachs of the western sparrow hawk, 3 in desert horned larks, 3 in western robins and one each in western meadowlark and thick-billed red-wing blackbird.

[1] Thomas, C. A. The predatory enemies of Elateridae (Coleoptera). Ent. News, 42: 159–163, 1931. Also Penn. Agr. Exp. Sta. Bul. 392, p. 32–5, 1940.

California gulls which commonly occur in large flocks of several hundred to 2000 and more and follow the plow each spring in hundreds of fields not too distant from the Great Salt Lake and Utah Lake, doubtless consume large numbers of wireworms as well as white grubs, cutworms and other injurious insects. Other insectivorous birds frequenting such fields at the time of plowing or harrowing also would be expected to pick up wireworms; these larvae are deeper in the soil later in the season and are probably less easily found and eaten by birds.—10-18-45.

**Table 1. The following table lists 29 species of insectivorous birds one or more of which were found to have recently fed upon adult Elateridae beetles. In addition, 10 wireworms were recognized in stomachs.**

| Bird Species | Click Beetles Recognized | Total Bird Stomachs | |
|---|---|---|---|
| | | Containing | Examined |
| Desert sparrow hawk | 2 | 3 | 242 |
| Sage grouse | 15 | 6 | 17 |
| California cuckoo | 1 | 1 | 1 |
| Poorwill | 2 | 2 | 2 |
| Nighthawk | 2 | 1 | 6 |
| Natalie sapsucker | 2 | 2 | 4 |
| Arkansas kingbird | 7 | 7 | 100 |
| Say phoebe | 4 | 4 | 23 |
| Little traill flycatcher | 1 | 1 | 3 |
| Wright flycatcher | 2 | 2 | 5 |
| Desert horned lark | 1 | 4 | 178 |
| Violet-green swallow | 1 | 1 | 14 |
| Rough-winged swallow | 1 | 1 | 9 |
| Barn swallow | 3 | 3 | 59 |
| Sage thrasher | 10 | 8 | 110 |
| Western robin | 6 | 6 | 28 |
| Townsend solitaire | 1 | 1 | 6 |
| American pipit | 4 | 4 | 103 |
| White-rumped shrike | 3 | 3 | 65 |
| Western meadow lark | 12 | 12 | 172 |
| Redwing blackbird | 5 | 6 | 76 |
| Brewer blackbird | 7 | 7 | 139 |
| Western tanager | 1 | 1 | 3 |
| Black-headed grosbeak | 1 | 1 | 3 |
| Western vesper sparrow | 3 | 3 | 106 |
| Sage sparrow | 1 | 1 | 46 |
| Western lark sparrow | 4 | 4 | 89 |
| Western chipping sparrow | 4 | 4 | 283 |
| Gambel sparrow | 2 | 2 | 126 |
| Total | 108 | 101 | 2,018 |

## *Labops* Damage to Range Grasses

GEORGE F. KNOWLTON, *Utah State Agricultural College, Logan*

*Labops tumidifrons* Knight (det. Dr. R. I. Sailer) was present in large numbers during the season of 1945 upon clumps of giant wild rye grass, *Elymus condensatus*, in the Laketown area of Utah near Bear Lake at an elevation of 6,010 feet. By mid-June of 1945, the yellowed, paler grass foliage could be recognized as seriously off-color at a distance approximately one-fourth mile from the affected area. The farmer who owned the pasture felt alarm, as this land normally produces a heavy growth of native bunch grass, used as pasturage for livestock during the winter when snow dampens the coarse foliage, making it palatable for cattle.

On July 18, 1945, hundreds of specimens of this bug were collected in a few sweeps of the insect net. From five to 175 bugs were counted on indi-

dividual bunches of grass. Each feeding puncture apparently resulted in production of a tiny round white spot on the leaf; several thousand such whitish dots were present on a large percentage of individual blades of grass. Much less spotting was present on grass stems and on the sheath parts which surrounded the stems.

The *Labops* infestation was confined chiefly to one low ridge, the bugs being scarce on bunch grass and other grass across a swale, only 6 to 8 rods away. One specimen of this bug also was picked up on wild rye grass in Logan Canyon; another on bunch grass at Garden City, both on July 18, 1945. A specimen was taken near Fish Haven, Idaho, July 15, 1945. Others were collected from large bunch grass at Monte Cristo, Utah, July 24, 1943 (G. F. Knowlton and D. R. Maddock).

Where giant wild rye grass gave way to dense growth of several other species of grass, on the margins of the low ridge near Laketown, the bugs were also feeding on and causing varying amounts of damage to at least five additional species of grasses. Least damage and only an occasional bug was noted upon a bluish meadow grass which occurred among the mixed-grass stand, though several other nearby grasses were damaged conspicuously. The damage decreased as the distance from the heavy growth of giant wild rye grass increased.

*Labops hesperius* Uhler was collected at the summit of Wolf Creek Pass, Utah, near the camp grounds spring, on July 24, 1945, at elevation about 9,000 feet. In one spot, on the meadow grass, there was a substantial concentration of these bugs, 88 being taken in 5 sweeps of the insect net. Typical pale feeding spots were present, resulting in moderate injury, on the grass in this area. Smaller numbers of *Labops* were taken in sweeps in several other parts of this small meadow area.

One to six *Labops hesperius* (det. R. I. Sailer) were taken per sweep of the insect net on giant rye, smooth brome and several other kinds of taller grasses at stops made within a mile of the summit in Wolf Creek Canyon, and along the West Fork of Duchesne River, Utah July 24, 1945, at elevations of 8000 feet and above. This species also was taken in moderate abundance on meadow grass and other grasses along streams at Strawberry Reservoir and Strawberry Creek, Utah, July 25, 1945. Damage was not serious. Previously E. W. Anthon had collected specimens in the Strawberry area on August 4 and 10, 1933 (det. H. G. Barber). A few specimens were collected upon grass, near stream, in upper Daniels Canyon, Utah, July 24, 1945, at an elevation of 7,850 feet.

*Labops hirtus* Knight was abundant, running about on the ground and feeding on range grass at Amalga, Utah, July 2, 1937 (det. H. G. Barber). Three specimens also were collected at Franklin, Idaho, on the same date.—11-10-45.

## Toxicity Tests of Certain N-Substituted 2,4-Dinitroanilines on Codling Moth Larvae

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The present paper gives the results of laboratory tests of certain *N*-substituted 2,4-dinitroanilines against the larva of the codling moth, *Carpocapsa pomonella* (L.).

All compounds were prepared by reacting 1-chloro-2,4-dinitrobenzene with the required amine. They may all be considered as derivatives of 2,4-dinitroaniline, in which one or both of the amino hydrogens are substituted by various groups. Where aromatic

**Table 1.—Toxicity tests of N-substituted 2,4-dinitroanilines against codling moth larvae.**

| COMPOUND | FORMULA | PERCENTAGE OF WORMY PLUGS |
|---|---|---|
| 2,4,4′-Trinitrodiphenylamine | $C_6H_3(NO_2)_2NHC_6H_4NO_2$ | 54 |
| *N*,*N*-Diethyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2N(C_2H_5)_2$ | 75 |
| *N*,*N*-Diisobutyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2N[CH_2CH(CH_3)_2]_2$ | 83 |
| *N*-Isobutyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2NHCH_2CH(CH_3)_2$ | 84 |
| *N*-Ethyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2NHC_2H_5$ | 87 |
| *N*-Isopropyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2NHCH(CH_3)_2$ | 89 |
| 3′-Methyl-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2NHC_6H_4CH_3$ | 92 |
| *N*-Ethyl-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2N(C_2H_5)C_6H_5$ | 92 |
| 4′-Chloro-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2NHC_6H_4Cl$ | 92 |
| 3′-Chloro-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2NHC_6H_4Cl$ | 92 |
| 2,4-Dinitro-*N*-propylaniline | $C_6H_3(NO_2)_2NHC_3H_7$ | 93 |
| *N*-Methyl-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2N(CH_3)C_6H_5$ | 93 |
| 2′-Methyl-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2NHC_6H_4CH_3$ | 93 |
| *N*-Amyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2NHC_5H_{11}$ | 94 |
| *N*-(2,4-Dinitrophenyl)-1-naphthylamine | $C_{10}H_7NHC_6H_3(NO_2)_2$ | 95 |
| *N*-Butyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2NHC_4H_9$ | 95 |
| 2′-Methoxy-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2NHC_6H_4OCH_3$ | 96 |
| *N*-(2,4-Dinitrophenyl)-2-naphthylamine | $C_{10}H_7NHC_6H_3(NO_2)_2$ | 97 |
| 4′-Methyl-2,4-dinitrodiphenylamine | $C_6H_3(NO_2)_2NHC_6H_4CH_3$ | 97 |
| *N*-Methyl-2,4-dinitroaniline | $C_6H_3(NO_2)_2NHCH_3$ | 97 |
| 1-(2,4-Dinitrophenyl)piperidine | $CH_2(CH_2)_4NC_6H_3(NO_2)_2$ | 98 |
| *N*,*N*′-Bis(2,4-dinitrophenyl)ethylenediamine | $C_6H_3(NO_2)_2NH(CH_2)_2NHC_6H_3(NO_2)_2$ | 99 |
| Lead arsenate | | 63 |
| Untreated check | | 96 |

groups were used as substituents, the compounds are named as derivatives of 2,4-dinitrodiphenylamine, except where naphthylamine, pyridine, and diethylamine were used. In these instances a different nomenclature is required.

The insecticidal evaluations were obtained by the apple-plug method. The number of apple plugs used in the tests were 301 for lead arsenate and 305 for the check (untreated), and ranged from 80 to 108 for the organic compounds. Each plug was infested with a single ready-to-hatch codling moth egg.

The sprays were used at the rate of 4 pounds to 100 gallons of a carrier which consisted of 20 per cent of ethanol (95 per cent) and 80 per cent of water by volume. The sprays were applied with a compressed-air sprayer.

The names and line formulas of the organic compounds tested and the results obtained in comparison with lead arsenate and check (untreated) tests are given in table 1.

2,4,4'-Trinitrodiphenylamine was slightly more effective than lead arsenate; for the most part, the rest of the compounds showed little to no toxicity.—11-24-45.

## Improved Dispenser for Testing New Liquefied-Gas Aerosols

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When insecticidal aerosols (Goodhue 1942) are tested for biological effectiveness, a specially calibrated dispenser must be used to measure the dosage under pressure. The dispenser first used for this purpose was described by Goodhue & Sullivan (1942). Later a dispenser measuring amounts down to 1 gram was described by McGovran *et al.* (1943). Both types were satisfactory for the aerosol formulas for use in tests by the Peet-Grady method, in use at that time, but the improved formulations have created a need for a new device to dispense less material. To meet this demand a dispenser that will deliver definite quantities down to 0.1 gram has been devised. It is similar to a dispenser recently described by Batt (1945), but is more simple in construction. A method of calibration is included and described below.

DESCRIPTION OF APPARATUS.—A longitudinal section of this dispenser is shown in fig. 1. A .75 inch brass pipe frame, *A*, 7.5 inches long, with two windows, .75 inch wide and 5.5 inches long, cut out on opposite sides, was threaded on one end with half-inch pipe threads, *B*, and on the other with a machine thread, *C*. A commercially available Y-valve, *D*, for small refrigerant drums was next fitted with a one-sixteenth inch i. d. tube, *E*, 2 inches long and screwed into the .375 to half-inch reducing bushing, *F*. The bushing was filled with molten solder and smoothed so that it would make a good seal against the neoprene (artificial rubber) washer, *G*. The tube *E* was next connected by a neoprene tube, *H*, to a graduated glass measuring tube, *I*, capable of indicating 0.1 gram.

Tube *H*, of optional length, was made by thickening a 10-mm. pyrex tube and drawing it down to equal tube *E* in diameter. It was graduated after having been calibrated according to the method to be described later in this paper. A heavy-walled pyrex test tube, *J*, 6.5 inches long, which fits loosely in the frame *A*, was used as a chamber. It was held in place against the neoprene washer, *G*, by a screw, *K*, with machine threads, which was provided with a leather washer, *L*, to protect the tube. A capillary nozzle, *M*, was made by soldering a reinforced piece of metal capillary, 0.018 inch i. d. and 4 inches long, into an eighth-inch pipe connection. This fits the connection *N* in the valve and screws down against the copper gasket, *O*. It is better to use a gasket than to depend on the threads to make the seal, because the threads wear rapidly.

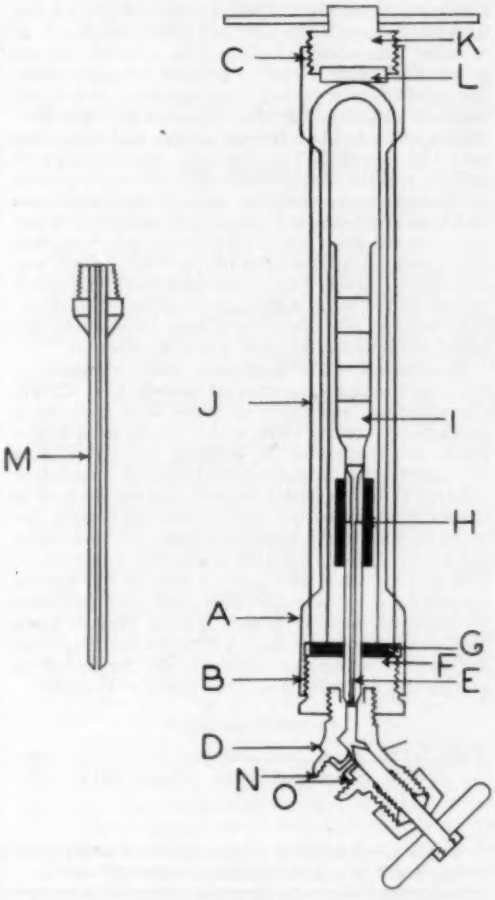


FIG. 1.—Improved methyl bromide dispenser.

CALIBRATION.—o-Dichlorobenzene, which has a density very close to the average density of the aerosol solutions in Freon-12 (dichlorodifluoromethane), was weighed into the tube in the amounts of 0.15, 0.3, 0.5, 1.0, and 2.0 grams, and temporary divisions were made on a paper scale. To complete the calibration a dyed aerosol solution of the following composition was used: o-dichlorobenzene 30, anthraquinone blue AB base 0.05, and *Freon-12*, 69.95 per cent.

The liquefied-gas solution was made up by the method of Goodhue & Sullivan (1942) in a container having a Y-valve of the type used on the dispenser.

Five grams of the solution was transferred to the pressure test tube described by McGovran *et al.* (1943), and the Y-valve was opened to allow the liquefied gas to boil away. (Methods of handling liquefied-gas solutions are also described in McGovran's paper.) The remaining o-dichlorobenzene and dye were transferred to a 500-ml. volumetric flask and diluted to the mark with acetone. The color was then determined on a photoelectric photometer in terms of transmission for 1 gram of liquefied-gas solution in 100 ml. of acetone. About 10 grams of the dyed liquefied-gas solution was introduced into the dispenser to be calibrated, and the greatest amount indicated by the temporary calibrations was dispensed through the capillary tube into 10 ml. of acetone. The acetone was held in a 50-ml. Erlenmeyer flask with a rubber stopper through which the capillary was passed, thus making a closed absorption chamber for the liquefied-gas solution. This was diluted to a known volume and compared with the standard. The dispenser was cleaned and refilled, and the next smallest amount was dispensed in the same manner, and so on until each mark was checked. The 1- and 0.5-gram marks delivered 96 per cent, the 0.3-gram mark delivered 90 per cent, and 0.15-gram mark gave only 66 per cent, which was actually 0.1 gram. The marks were finally adjusted to deliver 0.1, 0.25, 0.50, and 1.0 gram of solution. This method of calibration is very satisfactory because it indicates the exact amount delivered.

DISCUSSION.—The dispenser described above is the best of many experimental models. It is sturdy, easily cleaned, and easily operated. It is easily filled and adjusted to the mark, and it can be used to dispense two charges before refilling. Finally, it does not appreciably concentrate the small amount of solution to be dispensed, because the vapor phase is drawn from the entire solution instead of only the small amount in the calibrated tube. Since the aerosol solution passes through a slightly enlarged portion in the valve, the particle size of the aerosol formed by it is somewhat finer than that produced by some commercial aerosol bombs. Results show that this type of apparatus will give a more uniform kill than most aerosol bombs; hence the biological results can be duplicated more easily.—11-21-45.

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## Rate of Penetration of Nicotine into the Cockroach from Solutions of Various Hydrogen Ion Concentration[1]

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Although it now seems clearly established that nicotine penetrates the external body surface of insects and other organisms more rapidly as molecules than as ions, there are still questions concerning the toxic action of the absorbed nicotine that await solution. Most published information on this subject has been derived from studies in which mortality, or some physiological reaction, furnished the sole criterion of penetration. However, a direct relationship cannot be assumed to exist between time of death, or of the appearance of a physiological response, and the concentration of absorbed nicotine in the body of the organism. In any consideration of the relative resistance of insect species to nicotine, or to any other compound for that matter, information on the actual rate of penetration may become highly important.

In 1935, the late Dr. L. O. Ellisor and the writer undertook an investigation of the rate of entrance of nicotine into insects from solutions of several different *p*H values. It was intended to study a number of species known to differ widely with respect to nicotine susceptibility. Work was started on the American cockroach, *Periplaneta americana* (L.),

[1] Journal paper No. J-1333 of the Entomology and Economic Zoology Section of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 137.

**Table 1.—Entrance of nicotine into cockroaches from solutions of various hydrogen ion concentrations. Time 16 minutes; temperature 25°–26°C.**

| CONCN. OF NICOTINE, M. | pH OF SOLUTIONS | PERCENTAGE DISSOCIATION OF NICOTINE[2] | NO. OF INSECTS | NICOTINE ABSORBED MG. PER GRAM OF BODY WEIGHT | | | EFFECT ON INSECTS |
|---|---|---|---|---|---|---|---|
| | | | | Min. | Mean | Max. | |
| 0.05 | 9.3[1] | 4 | 15 | 0.37 | 0.45[3] | 0.55 | Nearly dead |
| 0.05 | 6.4 | 96 | 15 | .11 | .28 | .35 | 60% normal |
| 0.05 | 2.8 | 99.9+ | 15 | .18 | .24 | .30 | 83% normal |
| 0.002 | 8.7[1] | 12.4 | 10 | .02 | .03[3] | .05 | Normal |
| 0.002 | 5.0 | 99.8 | 10 | .01 | .02 | .02 | Normal |
| 0.002 | 2.6 | 99.9+ | 10 | .01 | .01 | .02 | Normal |

[1] Free base.
[2] From equation, $\log \alpha/1-\alpha = (pK_w - pK_b) - pH$ for 25°C.
[3] The differences between the mean values of absorbed nicotine for the 0.05M solutions are statistically significant (5 per cent probability level); the differences for the 0.002M solutions are not significant.

but had to be discontinued after a small series of tests was completed. It has not been possible since to resume the investigation. The present note concerns the data obtained in 1935.

Adult male and female cockroaches weighing 0.62 to 1.60 grams (mean weight 1.08 grams) were used in the tests. The nicotine was a redistilled sample containing 99 per cent of the alkaloid. The solutions for the tests were adjusted to the desired *p*H values by means of C.P. sulfuric acid. The *p*H values were determined electrometrically with a glass electrode apparatus.

A test was made by placing a cockroach in a small copper gauze cage into which the insect fitted snugly. The cage was then submerged in the nicotine solution until only the head and prothorax of the insect projected above the surface, in this way preventing entrance of nicotine into the digestive tract by imbibition. Time of submergence was fixed at 16 minutes, and the temperature of the solutions was held at 25° to 26° C. during the period of exposure. After exposure, the cockroach was removed from the cage, and washed in tap water and in distilled water to remove the surface nicotine. The absorbed nicotine in the entire insect was then extracted and determined quantitatively in the manner previously described )Glover & Richardson, 1936). The results of the tests are given in table 1.

The cockroach seems to absorb nicotine more rapidly from the air than from aqueous solutions. Thus, with a vapor concentration in air no greater than 0.27 milligram nicotine per liter, the insect absorbed 0.2 milligram per gram of body weight in 1 hour (Glover and Richardson, 1936), while from the 0.002M solutions (324 mgs. nicotine per liter), absorption was only about 0.03 milligram per gram in 16 minutes. The difference in time here is only 4-fold against a 1200-fold difference in the concentrations to which the insects were exposed, in the course of the tests.

The cockroach absorbs nicotine from aqueous solutions much more slowly than the goldfish, *Carassius auratus* (L). In 16 minutes the cockroach takes up from a 0.002M solution (*p*H 8.7), and is apparently unharmed by, a body concentration that kills the goldfish in less than 150 seconds (Ellisor & Richardson, 1938). "Innate resistance" may explain in part, the ability of the cockroach to withstand the larger dose of absorbed nicotine; but it appears likely that the much slower rate of absorption enables the cockroach to detoxify or otherwise to protect itself against the poison. The marked susceptibility of goldfish to nicotine is suggestive of the susceptibility of aphids and some other insect species to this poison. Perhaps the degree of susceptibility of insects to nicotine is largely the result of differences in rate of penetration of the nicotine into the body of the insect. At the present time, this appears to be an attractive hypothesis.

The results of these experiments confirm the greater toxicity and greater speed of penetration of nicotine molecules than of ions in a large, resistant, terrestrial insect. They also demonstrate the entrance of appreciable quantities of nicotine from solutions in which the alkaloid is almost completly ionized, and reveal a definite toxic effect of the absorbed nicotine (Richardson & Shepard, 1930).—11-21-45.

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## Coincident Infestations of *Aonidiella citrina* and *Coccus hesperidum*, a Result of Ant Activity

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Observations on the occurrence of yellow scale, *Aonidiella citrina*, in California since the estab'ishment of its parasite, *Comperiella bifasciata* How., in 1931 by the University of California show that the scale in *residential* districts has ceased to be a generally distributed pest of English ivy and citrus (Smith 1941).

Annual inspections since about 1939 of the orange trees growing along the street at 114 Terrace Avenue in Redlands, California, have shown certain of them to be chronically infested with yellow scale in spite of the presence of *Comperiella*. The chronic state of the yellow scale infestation, however, appeared to be correlated with the constant presence of the Argentine ant, the workers being engaged in collecting the honey dew excrement of the soft brown scale, *Coccus hesperidum*.

The yellow scale was quite generally distributed over each tree. The soft scale, however, was very localized, occurring densely in patches over which ants were swarming. Significantly the density of the yellow scale was greatest in the vicinity of the patches of soft scale.

All the parts of the tree infested with yellow scale appeared to be visited by one or more ants so frequently as largely to preclude oviposition by *Comperiella*. The *Comperiella* female requires considerable time to determine the suitability of the scale for oviposition and to perform the act of oviposition. At temperatures of about 80° F. the maximum rate of oviposition is about 3 eggs per hour (Flanders 1944). *Comperiella* is considerably smaller than the worker ant and is readily disturbed, if not destroyed, when the ant comes in contact with it during oviposition.

In order to show that the presence of ants on the orange trees is responsible for the infestation of yellow scale, an ant barrier in the summer of 1943 was placed on one of two trees which were adjacent to each other and about equally infested with yellow scale. The trunk of the tree, which was to be freed of ants, was coated with shellac and then banded with deadline.

During 1944 and 1945 the tree above this barrier was free of ants.

In the spring of 1945 an examination of 32 of the most heavily infested leaves from each tree showed that *Comperiella* was working much more effectively

on the banded tree than on the unbanded tree where the Argentine ant was attending the soft brown scale (Table 1). The soft brown scale on the banded tree had disappeared. This apparently was an effect of

**Table 1.—Parasitization by *Comperiella bifasciata* of mature yellow scale on 62 orange leaves from two street trees, one of which was free of ants for nearly two years. Material collected May 2, 1945.**

| Tree Freed of Ants | | | Tree Not Freed of Ants | | |
|---|---|---|---|---|---|
| Number of scales | | | Number of scales | | |
| | Not parasitized | | | Not parasitized | |
| Parasitized | 10%± alive | Total | Parasitized | 90%± alive | Total |
| 6 | 7 | 13 | 0 | 6 | 6 |
| 9 | 6 | 15 | 0 | 8 | 8 |
| 10 | 25 | 35 | 1 | 10 | 11 |
| 13 | 22 | 36 | 0 | 8 | 8 |
| 7 | 5 | 12 | 0 | 4 | 4 |
| 0 | 6 | 6 | 0 | 6 | 6 |
| 4 | 10 | 14 | 0 | 12 | 12 |
| 13 | 10 | 23 | 0 | 40 | 40 |
| 2 | 2 | 4 | 0 | 2 | 2 |
| 9 | 9 | 18 | 0 | 3 | 3 |
| 13 | 6 | 19 | 0 | 10 | 10 |
| 4 | 8 | 12 | 0 | 1 | 1 |
| 13 | 6 | 19 | 1 | 5 | 6 |
| 8 | 5 | 13 | 3 | 25 | 28 |
| 6 | 4 | 10 | 0 | 19 | 19 |
| 7 | 8 | 15 | 0 | 32 | 32 |
| 10 | 6 | 16 | 0 | 19 | 19 |
| 4 | 1 | 5 | 0 | 21 | 21 |
| 2 | 1 | 3 | 1 | 24 | 25 |
| 4 | 0 | 4 | 0 | 63 | 63 |
| 6 | 3 | 9 | 1 | 15 | 16 |
| 8 | 7 | 15 | 0 | 26 | 26 |
| 4 | 4 | 8 | 0 | 7 | 7 |
| 11 | 10 | 21 | 0 | 12 | 12 |
| 18 | 11 | 29 | 0 | 8 | 8 |
| 7 | 5 | 12 | 0 | 8 | 8 |
| 2 | 5 | 7 | 0 | 2 | 2 |
| 15 | 7 | 22 | 0 | 9 | 9 |
| 4 | 4 | 8 | 0 | 3 | 3 |
| 33 | 12 | 45 | 0 | 4 | 4 |
| 8 | 2 | 10 | 0 | 3 | 3 |

the absence of ants which either enabled the parasite *Metaphycus stanleyi* Comp. to destroy the scale or permitted the scale to drown themselves in their own excrement (Flanders 1943). A high proportion of dead unparasitized yellow scale on the banded tree indicated that many scales were destroyed by *Comperiella* merely through mutilation of the scale viscera by means of the ovipositor.

On October 29, 1945, examination of these two trees showed no live yellow scale on the banded tree while on the unbanded tree the infestation of yellow scale had increased considerably during the summer.

There were a few specimens of the red scale *Aonidiella aurantii* on both trees. None of this scale was parasitized.—11-13-45.

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## Hessian Fly Infestation in Tennessee and Kentucky

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About the middle of April 1945 farmers in the vicinity of Clarksville, Montgomery County, Tenn., noticed that the lower leaves of their wheat were turning yellow and that comparatively few heads had formed. The condition was somewhat more apparent in late-planted than in early wheat. Barley also was affected, but the injury was less severe than in wheat.

Observations in a wheatfield in which the symptoms were very noticeable disclosed a severe infestation of the hessian fly, *Phytophaga destructor* (Say). Every plant examined was infested, and it was not unusual to find 15 or more larvae and puparia at the base of a single stem. Approximately one plant in 10 had produced a single weak tiller bearing little or no grain. This field was considered a total loss in so far as the production of grain was concerned, but the owner made use of it as pasture. Similar damage was observed in other fields constituting possibly 5 per cent of the total acreage in Montgomery County.

Infestation was found in every field in which observations were made, and it is believed that appreciable damage occurred in all wheatfields in the county. These limited observations did not provide sufficient information for a satisfactory estimate of the total loss in Montgomery County, but it is believed that the agricultural agent's estimate of a 33 per cent reduction in yield of grain is not excessive. On a total of approximately 10,000 acres, with an average yield of 20.5 bushels per acre, the estimated loss in Montgomery County amounted to about 68,000 bushels having a value of at least $102,000. Similar losses were observed or reported in Robertson County, Tenn., and in Christian, Logan, Todd, and Trigg Counties, Ky.

The hessian fly is not considered a major pest of wheat in north-central Tennessee, and there is no authentic record of this insect having previously caused severe damage in Montgomery County, although there are reports of severe injury to wheat about 1910 by a "small white worm." There is evidence that the worms in question were hessian fly larvae.

The 1945 infestation was unusual in that severe damage was observed at least a month before the spring generation would have occurred normally. This damage was caused by a spring brood of flies emerging near the middle of March, when weather conditions were favorable for adult migration and hatching of eggs. Continued emergence of the regular brood of flies throughout April and the emergence of a supplementary brood in May greatly intensified the damage.

January temperatures averaged slightly below normal, but the lowest recorded was only 10° F. Subnormal temperatures continued through the first week in February, but from that time until April 15 the weekly average temperatures were from 3° to 16° above normal. Weekly average temperatures at Nashville for the 9-week period ending April 15 (Table 1) ranged from 46.3° to 69.4°. Pupation occurs at a mean temperature of 45° and above, and there was ample time before April 15 for an early spring brood to develop to the puparial stage. Hessian flies are most active and develop most successfully when the mean daily average tempera-

**Table 1.—Weekly precipitation and temperatures, and deviations from normal, as recorded at Nashville, Tenn., February 11 to April 15, 1945.**

| Week Ending | Temperature | | | | Precipitation |
|---|---|---|---|---|---|
| | Maximum | Minimum | Mean Daily Average | Average Daily Deviation from Normal | |
| | °F. | °F. | °F. | °F. | *Inches* |
| February 18 | 77 | 27 | 46.3 | +4.8 | 2.11 |
| 25 | 64 | 28 | 47.1 | +4.3 | 2.77 |
| March 4 | 77 | 31 | 48.7 | +4.0 | 2.90 |
| 11 | 76 | 33 | 49.8 | +3.1 | .06 |
| 18 | 83 | 44 | 64.7 | +16.0 | .39 |
| 25 | 80 | 34 | 58.8 | +7.8 | .69 |
| April 1 | 82 | 51 | 66.4 | +13.1 | .91 |
| 8 | 81 | 34 | 56.1 | +0.4 | .65 |
| 15 | 84 | 47 | 69.4 | +11.4 | T |

perature of the air is 55° to 65° and the humidity is high. These conditions prevailed after March 11 for a relatively long period. Total precipitation in February, March, and April was 14.73 inches, approximately 1.5 inches more than normal. A deficiency of 3.39 inches in March was more than overcome by excess rainfall in February and April. Examination of the March records, however, shows that rain fell on 16 days of the month, thus providing ample moisture for hessian fly development.

In general, the infestation was confined to green, succulent tillers, which indicated that the wheat had only recently become infested. Had the damage been done by a late-fall brood, most of the infested stems would have been comparatively dry and brown. The fact that the infestation was confined largely to late-planted wheat also indicates that the damage was done by an early spring brood.

Larvae of a second spring brood, which were moderately abundant the latter part of May, damaged small succulent tillers of late-planted wheat, but this damage was much less severe than that caused by the earlier brood.—10-3-45.

## Chinch Bug Dust Barrier: Preliminary Tests[1]

R. R. WALTON, *Oklahoma Agricultural Experiment Station, Stillwater*

Due to the shortage of creosote in recent years large quantities of a dinitro[2] dust have been used in chinch bug control work. Decker (1943) showed various dinitro compounds to be toxic to chinch bugs and pointed out the advantages and disadvantages of constructing and maintaining dust barriers. The following report is on work done to test chemical dust barriers under conditions existing in Oklahoma.

Tests were made in the field and under modified field conditions, comparing creosote, dinitro-ortho-cresol (*DN*), sabadilla and DDT as barrier materials. The creosote was a coal tar type used in the past by the Oklahoma Extension Division in control work. Chinch Bug Barrier Dust (*DN* dust), supplied by the U. S. Department of Agriculture, consisted of 2 and 4 per cent concentrations of dinitro-O-cresol in pyrophyllite. Sabadilla dusts contained a 1:1 ratio of ground seed and lime mixed with various proportions of *Pyrax ABB*. The 5 per cent DDT dust was made by mixing equal parts of *Gesarol A-10*-dust and *Pyrax ABB*.

In an attempt to obtain quantitative data on the effectiveness of barriers during a period of 1 to 4 days after construction, a small scale modified field test method was employed. A ring barrier 24 inches in diameter was constructed on a 2-inch thickness of tamped soil resting on the top of a circular wooden platform having a diameter of 30 inches. The platform was encircled with a metal rim extending ½ inch above the surface of the soil. The platform was supported, at a height of 30 inches from the ground, over the mouth of a galvanized metal funnel 40 inches in diameter. The funnel was supported by a small framework in such a position so that its spout enclosed the stem of a growing sorghum plant. Cheesecloth was used as padding to make the opening around the plant stem bugtight. Several hundred chinch bugs, mainly in the nymphal stage, were collected from sorghum plants and placed on the soil in the center of the ring where they could attempt to cross the barrier. Those that crossed dropped from the platform into the funnel where they were shunted to the bottom near the stem of the food plant. A light line of creosote was applied around the top of the funnel to prevent escape of bugs that occasionally crawled up the funnel sides. At the end of the test period the plant was cut off immediately below the funnel and the bugs were dislodged from the funnel into a jar held below the sprout. The jar was taken to the laboratory, where counts were made to determine the percentage of mortality. The living bugs in the jar were placed in a cage containing food in the laboratory and kept for 6 days after they had crossed the barrier. At this time counts of dead and living bugs were again made.

The results obtained by using the various dust barriers are given in table 1. With the exception of those placed in rings of 10 per cent sabadilla, the great majority of bugs crossed the barriers in 10 to 20 minutes. Since only bugs that crossed barriers were included in the records, the percentage of mortality obtained for certain of the materials is lower than the actual kill that occurred. In the case of 10 per cent sabadilla an estimated 15 to 25 per cent died without crossing the barrier. The same was true to a lesser degree in the cases of 5 per cent

[1] Approved by the director of the Oklahoma Agricultural Experiment Station.
[2] Dinitro-ortho-cresol

**Table 1.—Small scale chinch bug barrier tests, Stillwater, 1945.**

| Date[1] | Test No. | Mortality, Per Cent | | | | | | | | Conditions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *DN* | | Sabadilla | | | DDT 5% | | Untreated | Test Period | Age of Barrier | Ounces Per Rod | Unfavorable Weather Conditions |
| | | 4% | 2% | 10% | 5% | 2% | At end of Test Period | At end of 6 days | | | | | |
| | | | | | | | | | | *Hours* | | | |
| June 30 | 1 | 67.2 | 27.5 | 100.0 | | | | | 3.0 | 6 | 1 | 4 | |
| June 31 | | | | | | | | | | | | | Rain |
| July 2 | 2a | 86.8 | 36.1 | 99.0 | 95.9 | | | | 2.1 | 24 | 1 | 4 | |
| July 3 | 2b | 57.8 | 22.8 | 100.0 | 92.0 | | | | 0.1 | 24 | 24 | 4 | Heavy dew |
| July 4 | 2c | 56.1 | 40.0 | 100.0 | 98.9 | | | | 1.5 | 24 | 48 | 4 | Heavy dew |
| July 5 | 2d | 31.7 | 30.2 | 99.4 | | | | | 1.4 | 9 | 72 | 4 | Heavy dew |
| Test Average | | 58.1 | 32.3 | 99.6 | | | | | 1.3 | | | | |
| July 6 | | | | | | | | | | | | | Rain |
| July 7 | 3a | 98.6 | 88.8 | | 100.0 | 59.9 | | | 2.5 | 24 | 1 | 8 | |
| July 8 | 3b | 65.0 | 57.4 | | 98.6 | 16.2 | | | 3.3 | 24 | 24 | 8 | Dew |
| Test Average | | 81.3 | 73.1 | | 99.3 | 38.1 | | | 2.9 | | | | |
| Aug. 27 | 4a | | 74.6 | | 97.2 | 44.2 | 50.4 | 81.9 | | 40 | 1 | 10 | |
| Aug. 28 | 4b | | 45.7 | | 26.1 | 9.8 | 21.5 | 47.7 | 2.5 | 40 | 24 | 10 | Gusty wind |
| Aug. 30 | 4c | | 22.0 | | 17.5 | 15.1 | 10.6 | 66.3 | 3.5 | 40 | 72 | 10 | Gusty wind |
| Aug. 31 | 4d | | 56.1 | | 41.3 | 45.7 | 38.8 | 80.1 | 4.0 | 30 | 96 | 10 | |
| Test Average | | | 49.6 | | 45.5 | 33.7 | 30.3 | 69.0 | 3.3 | | | | |
| Sept. 1 | 5a | | 82.1 | 91.4 | 76.2 | | 43.5 | | | 51 | 1 | 8 | |
| Sept. 3 | 5b | | 74.7 | 92.8 | 74.0 | | 42.4 | | 5.1 | 52 | 48 | 8 | |
| Sept. 5 | 5c | | 41.0 | 77.4 | 66.6 | | 37.1 | 48.4 | | 52 | 96 | 8 | |
| Test Average | | | 65.9 | 87.2 | 72.3 | | 40.3 | 48.4 | 5.1 | | | | |

[1] Tests made from June 30 to July 8 were on first generation nymphs while those conducted during August and September were on second generation nymphs.

sabadilla and 4 per cent *DN*. The mortality rate of bugs placed on platforms having no barriers (untreated checks) was low, nearly all reaching the food plant where they remained during the test period. The 10 per cent sabadilla was the most effective material tested, its effects being very rapid and severe. Under conditions of heavy dew and excessive soil moisture, the 10 and 5 per cent strengths of sabadilla were more effective than the *DN* dusts. Pronounced discoloration and caking of the latter materials occurred under these conditions. Brushing of the surfaces of barrier lines did not appear to neutralize the effects of moisture to any considerable extent. In tests made under dry conditions, August 27 to September 5, *DN* 2 per cent dust was equally effective as 5 per cent sabadilla while 10 per cent sabadilla appeared to be better than either of these dusts. In the few tests made, 2 per cent sabadilla and 5 per cent DDT (on the basis of counts made at the end of 30- to 52-hour test periods) were distinctly less effective than the other dusts. However, counts made 6 days after exposure to barriers indicated DDT continued to kill a considerable percentage of bugs after the regular test period while little additional kill was caused by the other materials. Because of this fact, data for the 6-day period counts are presented only for the DDT. Although the platforms were protected to some extent by being placed in the north margin of a sorghum field, gusty winds reduced the effectiveness of barriers by sweeping bugs over them and by eroding dust lines. Due to the deteriorating effect of weather factors there was a general decrease in effectiveness of barriers as their age increased.

During the period June 19 to 29, 2 per cent and 4 per cent concentrations of *DN* dust were compared with standard creosote barriers in field tests. Five 150-foot barrier sections, two of each dust concentration and one of creosote, were constructed between the margins of a wheat field and a corn field. Conditions were very unfavorable for the use of dusts as barriers. Total precipitation during the period was estimated to be about 4 inches, coming in three rains each of which completely destroyed all dust barriers. These barriers were constructed five times, using a total of approximately 1.8 pounds of dust per rod. Creosote was applied two times, using about one half gallon on the 150-foot section. Although the *DN* dust barriers killed large numbers of bugs during the short periods when they were dry, each time following their destruction by rain bugs invaded the corn, necessitating moving the barrier lines further into the corn field. By June 29, when a considerable portion of the bugs had reached the adult stage, the corn field was penetrated to the 8th or 9th row beyond the original barrier lines. No appreciable numbers of bugs crossed the creosote barrier.

In connection with the above field test some information was obtained on the hazards of poisoning turkeys in the use of *DN* dust. No harmful effects were observed to occur to a large flock of young and mature turkeys that ranged over the field during the 10-day test period. To supplement this observation, two 10-week-old poults were placed in a cage house similar to the one in which they were reared and supplied with regular feed and water. A band of 2 per cent *DN* dust was applied at a rate of approximately 1 pound per rod. During a period of three days the birds were observed several times to approach the dust and peck at it in a casual manner. Feeding and drinking appeared to be normal during this period and apparently no injury was sustained —11-13-45.

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## *N*-Substituted *p*-Toluenesulfonamides to Control Codling Moth Larvae

E. H. SIEGLER and S. I. GERTLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Toxicity tests against larvae of the codling moth, *Carpocapsa pomonella* (L.), on some aryl *N*-substituted benzamides were reported by Siegler & Bowen (1942), on certain *N*-substituted *p*-bromobenzenesulfonamides by Siegler and Gertler (1943), and on several *N*-substituted benzamides by Siegler and Gertler (1944). The present paper gives the results obtained in a study of certain *N*-substituted *p*-toluenesulfonamides against the codling moth.

All the compounds were prepared by allowing *p*-toluenesulfonyl chloride to react with various amines. These amines included primary and secondary aliphatic amines, aryl and substituted aryl amines, carbocyclic and heterocyclic amines, a mixed aliphatic aromatic secondary amine, and an aliphatic diamine.

The toxicological evaluations of the compounds were made by the apple-plug method. Approximately 100 plugs, each infested with a ready-to-hatch codling moth egg, were used for each test material. The plugs were sprayed with each compound at the rate of 4 pounds to 100 gallons of ethanol (20 per cent).

The toxicological data for this study are given in table 1. The compounds were ineffective.—9-10-45.

**Table 1.—Results of tests of certain *N*-substituted *p*-toluenesulfonamides against codling moth larvae.**

| | Name of Compound | Formula | Percentage of Plugs— Wormy | Stung |
|---|---|---|---|---|
| I | *N*-Propyl-*p*-toluenesulfonamide | $C_6H_4(CH_3)SO_2NH(CH_2)_2CH_3$ | 86 | 3 |
| II | *N*-Isobutyl-*p*-toluenesulfonamide | $C_6H_4(CH_3)SO_2NHCH_2CH(CH_3)_2$ | 99 | 0 |
| III | *N*-sec-Butyl-*p*-toluenesulfonamide | $C_6H_4(CH_3)SO_2NHCH(C_2H_5)CH_3$ | 86 | 0 |
| IV | *N,N*-Diethyl-*p*-toluenesulfonamide | $C_6H_4(CH_3)SO_2N(C_2H_5)_2$ | 85 | 0 |
| V | *N,N*-Diisobutyl-*p*-toluenesulfonamide | $C_6H_4(CH_3)SO_2N[CH_2CH(CH_3)_2]_2$ | 95 | 0 |
| VI | *N*-Benzyl-*p*-toluenesulfonamide | $C_6H_4(CH_3)SO_2NHCH_2C_6H_5$ | 96 | 0 |
| VII | *p*-Toluenesulfono-*o*-toluide | $C_6H_4(CH_3)SO_2NHC_6H_4CH_3$ | 96 | 0 |
| VIII | *p*-Toluenesulfono-*m*-toluide | $C_6H_4(CH_3)SO_2NHC_6H_4CH_3$ | 89 | 0 |
| IX | *p*-Toluenesulfon-*o*-aniside | $C_6H_4(CH_3)SO_2NHC_6H_4(OCH_3)$ | 93 | 6 |
| X | *p*-Toluenesulfono-*o*-phenetide | $C_6H_4(CH_3)SO_2NHC_6H_4(OC_2H_5)$ | 94 | 0 |
| XI | *N*-Ethyl-*p*-toluenesulfonanilide | $C_6H_4(CH_3)SO_2N(C_2H_5)C_6H_5$ | 93 | 1 |
| XII | *N*-Cyclohexyl-*p*-toluenesulfonamide | $C_6H_4(CH_3)SO_2NHCH(CH_2)_4CH_2$ | 94 | 0 |
| XIII | 4-(*p*-Tolylsulfonyl)morpholine | $C_6H_4(CH_3)SO_2N(CH_2)_2OCH_2CH_2$ | 96 | 0 |
| XIV | 1-(*p*-Tolylsulfonyl)piperidine | $C_6H_4(CH_3)SO_2N(C_2H_4)CH_2$ | 99 | 0 |
| XV | *N,N'*-Bis(*p*-tolylsulfonyl)ethylenediamine | $C_6H_4(CH_3)SO_2NH(CH_2)_2NHSO_2C_6H_4CH_3$ | 89 | 2 |
| Check (untreated), average for 4 tests | | | 96 | 1 |

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## Ethyl Formate and Isopropyl Formate as Fumigants for Packages of Dried Fruits

PEREZ SIMMONS and CHARLES K. FISHER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Ethyl formate has been successfully used for individual-package fumigation of dried fruits since 1927. The process, which is in sequence with the other operations of the packing line, consists in pumping a small quantity of the fumigant into the package just before the dried fruit is put in. The package is sealed immediately thereafter, and the resulting exposure to the gas kills any insects or their eggs that may have escaped removal during cleaning and washing operations.

The usual dosage of ethyl formate for a 25-pound box of raisins (0.41 cubic foot) ranges from about 4 ml. in hot weather to 7 ml. in cold weather, and for the well-sealed wartime "arsenal" cases (0.52 cubic foot) it is 4.5 or 5 ml. The treatment is said to be more effective when used in solid fiberboard cases than in fluted ones and is not effective in wooden boxes unless they contain a paper-bag liner. The liner most commonly used is made of No. 21 plain kraft paper, although for some raisins oiled or wax-impregnated paper is used. The liners are opened and fitted into the case before the fruit is poured in, after which the top is folded down. Dosages for different kinds of packages should be determined by experimental exposures of insects sealed in with the contents.

As ethyl formate is an organic solvent and removes protecting films from metal, iron and steel parts may become somewhat corroded where it is used.

Ethyl formate is a colorless liquid weighing about 7.6 pounds per gallon at 68° F. Its boiling point is 129.4° F., and it has an explosive range of from 2.5 per cent (about 5 pounds per 1,000 cubic feet) to 14 per cent by volume. When breathed it is mildly anaesthetic and irritates the respiratory membranes. A pound contains about 500 ml. and costs approximately 24 cents (November 1945) when obtained in 400-pound returnable drums.

A similar fumigant, isopropyl formate, is about as effective, volume for volume, as ethyl formate and its cost per pound is practically the same. It weighs about 7.3 pounds per gallon at 68° F., and there are approximately 520 ml. in a pound. The explosive range is given by the manufacturer as 2.4 to 8.6 per cent by volume. Its boiling point is about 160.4° F.

Only ethyl and isopropyl formates of high purity should be used in the fumigation of dried fruits.

Because, like all fumigants, ethyl formate and isopropyl formate are poisons, adequate means should be provided for carrying their fumes away from workers. Furthermore, since they present a fire hazard at certain concentrations, it is recommended that a ventilating hood be installed over the point where the liquid is released into the packages.

Sources of these formates are as follows:[1]

Ethyl formate: Braun-Knecht-Heimann Company, 1400 16th St., San Francisco 19, Calif., and Commercial Solvents Corporation, Terre Haute, Ind.

Isopropyl formate: Neil A. Maclean Company, 470 Eighth St., San Francisco 3, Calif., and Dow Chemical Company, Midland, Mich.

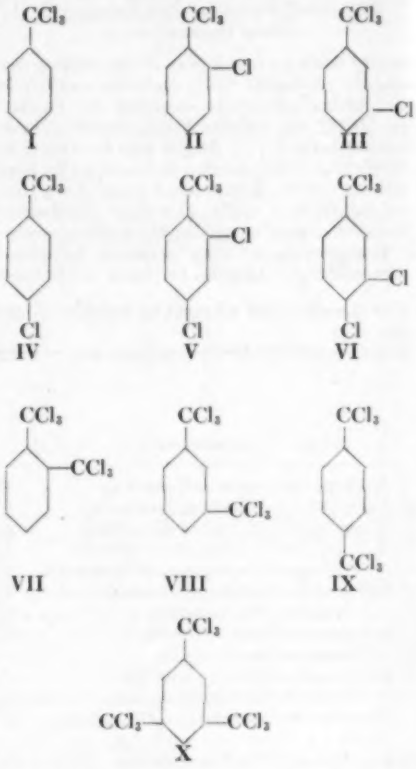
Applicators for these fumigants may be constructed or purchased ready made. Formate applicators are made by L. A. Crow and Company, 1826 Mono St., Fresno 1, Calif., and Fiese and Firstenberger, East Kern and Angus Sts., Fresno 1, Calif. Isopropyl formate may be applied with applicators obtainable from Neil A. Maclean Company (address above), or with a dispenser known as the Fisher Volustat, which has a capacity up to 5 ml. and is sold by the Fisher Scientific Company, 711–723 Forbes St., Pittsburgh 19, Pa.—11-13-45.

[1] These sources of formates and applicators are given for the convenience of the public and the Department does not guarantee or endorse these firms or the reliability of their products. No claim is made that the list is complete, and no discrimination is intended against any manufacturer not included.

## Alpha-Trichloromethyl-Substituted Benzenes to Control Codling Moth Larvae

E. H. SIEGLER and ELMER E. FLECK, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The compound 1-trichloro-2,2-bis(*p*-chlorophenyl) ethane, now usually referred to as DDT, has shown outstanding promise against larvae of the codling moth *Carpocapsa pomonella* (L.). The presence of an alpha-trichloromethyl group in DDT raises the question as to whether this group exerts a marked influence upon the toxicity of benzene derivatives containing such groups. To determine this point a number of simple benzene derivatives containing alpha-trichloromethyl groups have been prepared and tested against codling moth larvae. The structural formulas of the compounds are given below:




The ortho, meta, and para monochloro derivatives and two dichloro derivatives of alpha-trichlorotoluene were prepared and tested. A second series consisted of two trichloromethyl groups arranged in the ortho, meta, and para positions to each other. Finally, mesitylene with three trichloromethyl groups attached on alternate carbon atoms of the benzene ring was made and tested.

These compounds were prepared by the chlorination of the corresponding methylbenzenes (French Patent No. 798,727, May 25, 1936) at temperatures between 100° and 150°C. in the presence of ultraviolet light.

The toxicological studies were made by the apple-plug method, in which approximately 100 plugs were used for each compound. A single ready-to-hatch codling moth egg was used to infest each plug.

The compounds were prepared for spraying by first treating them with sufficient ethanol (95 per cent) to make the ultimate carrier 20 per cent ethanol by volume. In some cases solution was obtained with ethanol at room temperature, but in others heating was necessary. Water was then added to the solution to make the strength 4 pounds to 100 gallons.

As indicated by the data given in table 1, none of the compounds showed satisfactory effectiveness. Alpha, alpha′, alpha″-nonachloromesitylene, with the highest number of chlorine atoms, was

**Table 1.—Effectiveness of some alpha-trichloromethyl-substituted benzenes against codling moth larvae.**

| NAME OF COMPOUND | FORMULA | APPLE PLUGS WORMY | APPLE PLUGS STUNG |
|---|---|---|---|
| | | *Per Cent* | *Per Cent* |
| I alpha-Trichlorotoluene | $C_6H_5CCl_3$ | 92 | 1 |
| II alpha, alpha, alpha, 2-Tetrachlorotoluene | $ClC_6H_4CCl_3$ | 83 | 0 |
| III alpha, alpha, alpha, 3-Tetrachlorotoluene | $ClC_6H_4CCl_3$ | 88 | 0 |
| IV alpha, alpha, alpha, 4-Tetrachlorotoluene | $ClC_6H_4CCl_3$ | 90 | 0 |
| V alpha, alpha, alpha, 2,4-Pentachlorotoluene | $Cl_2C_6H_3CCl_3$ | 93 | 3 |
| VI alpha, alpha, alpha, 3,4-Pentachlorotoluene | $Cl_2C_6H_3CCl_3$ | 96 | 1 |
| VII alpha, alpha'-Hexachloro-*o*-xylene | $C_6H_4(CCl_3)_2$ | 94 | 0 |
| VIII alpha, alpha'-Hexachloro-*m*-xylene | $C_6H_4(CCl_3)_2$ | 95 | 0 |
| IX alpha, alpha'-Hexachloro-*p*-xylene | $C_6H_4(CCl_3)_2$ | 91 | 0 |
| X alpha, alpha', alpha''-Nonachloromesitylene | $C_6H_3(CCl_3)_3$ | 79 | 4 |
| Check (no treatment)—average for 4 tests | | 90 | 0 |

somewhat more toxic than the other compounds. Differences in chemical constitution did not modify toxicity.

## Ethylene Dibromide as a Fumigant for the Japanese Beetle

A. C. MASON and R. D. CHISHOLM,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Preliminary investigations begun in the spring of 1945 have indicated that ethylene dibromide is highly effective against all stages of the Japanese beetle, *Popillia japonica* Newm. These investigations involved the use of this compound as a fumigant for larvae, pupae, and eggs in soil and for adults under atmospheric conditions. The toxicity of ethylene dibromide to Japanese beetle larvae had been noted in 1930 by the late F. E. Baker.[2]

At room temperature ethylene dibromide is a colorless liquid. It has a density of 2.1701 (25°/4°C.), a boiling point of 131.6°C. (268.9°F.), and a melting point of 10.0°C. (50.0°F.).

Since ethylene dibromide is a solid under some conditions of use, it was diluted with ethylene dichloride (melting point −35.3° C. (−31.5° F.)) to form mixtures having suitable melting points. These mixtures plus a surface-active agent were used in tests with immature stages of the Japanese beetle according to the methods described by Mason *et al.* (1943). The earlier study established the fact that relatively large doses of ethylene dichloride are required to kill all larvae; therefore, the low concentrations of this compound used in the present tests had little toxicity. Two stock mixtures were used as follows (figures in per cent by weight):

| | *Formula 1* | *Formula 2* |
|---|---|---|
| Ethylene dibromide | 16.0 | 62.0 |
| Ethylene dichloride | 81.5 | 36.0 |
| Tween 20 (a polyoxyalkylene derivative of sorbitan monolaurate) | 2.5 | 2.0 |

[1] The authors gratefully acknowledge the assistance of L. W. Coles throughout these investigations.
[2] Unpublished data.

The products, which contain slightly less than 10 and 50 per cent of ethylene dibromide, respectively by volume, are prepared by mixing the several ingredients uniformly, to form clear solutions. The solutions are diluted for use by vigorous shaking with 1 to 2 volumes of water to form a milky emulsion. This emulsion is then diluted to the desired volume by adding water and stirring. In general, substantially clear solutions will result if the stock mixtures are used at rates of 10 ml. or less per gallon of water. At higher concentrations cloudy suspensions are formed which consist of part of the fumigant in solution and the remainder in an emulsified form. The condition of the final mixture will de pend on the temperature.

It was found that third-instar larvae in plant balls were killed by dipping the infested balls for 10 seconds in solutions prepared from the 62 per cent mixture at concentrations as low as 0.63 ml. per gallon of water. The larvae remained in the treated balls for 24 hours following treatment at temperatures ranging from 40° to 70° F., and almost all of them died within 1 to 10 days after removal. Larvae in 1-inch cubes of soil were killed following similar treatment with a solution prepared from the 16 per cent mixture at the rate of 2.5 ml. per gallon at temperatures from 50° to 70°. About the same length of time was required for mortality to take place. Bare larvae were killed following immersion for 10 seconds in an emulsion prepared from the 16 per cent mixture at the rate of 30 ml. per gallon, or from the 62 per cent mixture at the rate of 20 ml. per gallon. Larvae in turf located in the upper 4 inches of a loam soil at temperatures from 60° to 80° were killed after a solution prepared from the 16 percent mixture at the rate of 10 ml. per gallon had been applied at the surface at the rate of 1 gallon per square yard. In nurseries a dosage of 20 ml. per gallon was required to kill larvae located as deep as 10 inches in loam and clay soils at 50°. In all cases most of the larvae were dead when removed 7 days after treatment. A few survived for additional periods ranging up to 10 days.

Pupae in plant balls were killed by immersing the balls at 70° F. for 10 seconds in a solution prepared from the 16 per cent mixture at the rate of 5 ml. per gallon. In square-yard plots of a sandy-loam soil at 70°, 8 ml. of the 62 per cent mixture applied to the surface of the plot in 1 gallon of water was required

to kill all the pupae. A dosage of 20 ml. of the 16 per cent mixture in 1 gallon of water killed about 98 per cent of the pupae under similar conditions. The mortality of all pupae was delayed, as was the case with the larvae.

Eggs in soil masses at 70° F. were generally killed following immersion of the masses for 10 seconds in solutions containing 5 or 10 ml. of the 16 per cent mixture per gallon of water. In some of the lots none of the eggs hatched, but a few first-instar larvae were recovered from other lots. These tests indicate that ethylene dibromide is a highly effective ovicide.

In the tests with adult beetles ethylene dibromide was heated to about 125° F. within a fumigation chamber. As the vapors were evolved, they were withdrawn from the heating unit, mixed with air, and dispersed throughout the chamber by means of a circulating fan. The beetles were killed byexposure for 2 hours to a dosage of 0.5 pound of ethylene dibromide per 1,000 cubic feet throughout the temperature range of 50° to 70°.

Preliminary tests indicate that plants will tolerate only small doses of ethylene dibromide; however, several kinds of plants were not injured by the dosages found to be lethal to the immature stages of the Japanese beetle. The tolerance of specific varieties has not been established. Fumigation at the dosage and exposure period required to kill Japanese beetles did not injure several kinds of fruits and vegetables.

These preliminary tests indicate that ethylene dibromide is a useful insecticide for the control of the Japanese beetle. At the dosages required it is relatively cheap and is easy to apply.—11-17-45.

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## Bacterial Infections of Potato Tuber Moth Larvae in an Insectary[1]

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The larva of the potato tuber moth, *Gnorimoschema operculella* (Zell.), is used as an insectary host for the mass production of the hymenopterous parasite *Macrocentrus ancylivorus* Roh., which is being distributed in California to aid in the control of the oriental fruit moth, *Grapholitha molesta* (Busk.). The method of rearing the parasite in the insectary concerned in this report is very similar to that described by Finney, *et al.* (1944).

Ever since production of the parasite was initiated in 1943 a small number of tuber moth larvae have regularly been found dead in the rearing trays and on the sand-covered cocooning cards. Gross examination of the dead and dying larvae showed them to have symptoms characteristic of bacterial diseases. Infected individuals would become sluggish in movement, less sensitive to external stimuli, would refuse to eat and frequently were diarrheic. Upon death, the larvae were observed to be either dark brown to black in color or bright red, the latter turning brown upon subsequent disintegration. The red coloration was of a considerably deeper shade and occurred more uniformly throughout the insect than does the faint pink coloration seen in normal larvae of this species. Blackened larvae were seen approximately three times as often as were red specimens. Occasionally the infected larvae were capable of going into the pupal stage, after which they would assume the black or red color of diseased individuals.

Microscopic examinations of crushed specimens of these dead or dying larvae revealed extremely large numbers of small rod-shaped bacteria—a situation rarely seen in normal, healthy larvae. Examinations for microsporidia and for polyhedra gave negative results.

Representative specimens of the diseased larvae were cultured on nutrient agar, nutrient blood (sheep) agar, yeast extract agar, and occasionally on North's gelatin-chocolate-blood agar. Abundant growth was usually obtained on all these media. Generally speaking, three bacterial species were repeatedly but separately isolated, frequently in pure culture, from the diseased specimens.

From the larvae which had turned deep red in color, a deep-red-colored strain of what proved to be *Serratia marcescens* Bizio was invariably isolated. From the larvae which had turned brown to black upon dying, two gram-negative, nonsporeforming, small rods were separately isolated. One of these rods was repeatedly isolated from larvae dying between July 21 to 25; the other from larvae dying between July 26 to 31, 1945. The only difference in the production procedures between these two periods was in the use of a new lot of potatoes upon which the larvae were propagated. One of these bacteria appeared to be a strain of *Aerobacter*, probably *Aerobacter cloacae* (Jordan). The other rod was not definitely identified, although it appeared to be a coliform of the slow lactose-fermenting group. Some of the strains of the latter organism were markedly hemolytic for sheep erythrocytes.

In many of those instances in which *Serratia marcescens* was isolated, the bacterium grew out in pure culture. Of particular interest, from a bacteriological viewpoint, is the fact that upon subsequent transfer, none of the strains isolated showed the dissociation into the pink and white colonies usually seen with this species. After numerous transfers these strains still yielded a uniform growth of deep red colonies. Attention is called to the fact that *Serratia marcescens* has been known to cause disease and death in other species of insects (see Steinhaus, 1942).

Further indication of the pathogenicity of the three strains isolated was obtained by a series of feeding and inoculation experiments. In general, the results showed the tuber moth larvae to be susceptible to all three strains, both when the bacteria were inoculated into the body cavity and when they were fed to the larvae. As might be expected, the larvae were more susceptible to the bacteria when the latter were inoculated into the insects than when given to them orally.

Cultures made of washings of the various equipment (e.g., puncturing board, operator's gloves, cocooning sand, and egg sheets) used in rearing the larvae, showed the species of bacteria concerned to

[1] For most of this work the facilities of the Department of Bacteriology, University of California, were used. Normal and diseased specimens were furnished by Blair Bartlett, Charles Martin and Glenn Finney of the Division of Beneficial Insect Investigations.

be uniformly present. It is very likely that the ultimate source of the bacteria were the potatoes used to rear the larvae. Not only is this indicated by the fact that the natural habitat of all three species of bacteria includes the soil in which potatoes are raised, but also by the isolation of the bacteria directly from washings of the sacked potatoes prior to use.—11-10-45.

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## Toxicity of Benzene Hexachloride to Housefly Larvae

E. R. MCGOVRAN and P. G. PIQUETT, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The toxicity of benzene hexachloride (1,2,3,4,5,6-hexachlorocyclohexane; called 666 in England) to insects and mites has been reported. Slade (1945, a and b) reported that the gamma isomer of benzene hexachloride and mixtures containing it had been found to be highly toxic to locusts, cockroaches, wireworms, caterpillars, lice, fleas, houseflies, blowflies, mosquito larvae, various beetles and weevils, sheep scab, and poultry red mite. Gersdorff & McGovran (1945) found a sample of this material, which was received from England,[1] to be more toxic than DDT to houseflies, *Musca domestica* L., when applied as a contact kerosene-base spray. Taylor (1945) reported benzene hexachloride to be very effective when used as a 1 per cent solution in liquid paraffin for controlling the mite *Notoëdres muris* (Megnin) on rats.

In this investigation the comparative toxicity of benzene hexachloride, DDT, borax, and thiourea to housefly larvae was determined.

A quantity of crushed oats was treated with an acetone solution of benzene hexachloride or DDT to give the desired concentration of toxicant. The acetone was then evaporated. Twenty-three grams of the treated oats was then placed in each of several pint glass jars with screen tops. Thirty milliliters of a mixture of yeast, syrup, and water was also added to each jar (McGovran & Piquett 1943). In tests with borax and thiourea the toxicant was dissolved in water and the desired concentration was obtained by substituting one of these aqueous solutions of toxicant for part of the 30 ml. of aqueous solution added to all the jars. Twenty-five third instars were added to each jar, and 4 days later 50 ml. of dry sand was placed on the surface of the media in the jars. The jars were held at 75° F. and 75 per cent relative humidity until all the flies that survived had emerged. The recorded survival was based on the number of adult flies emerging in each jar. After several preliminary experiments had established the approximate level of toxicity for the 4 insecticides, each material was tested at 3 concentrations, and each test was run 3 times in duplicate, making a total of 18 tests on each insecticide in the final series.

The concentrations of toxicant, in parts per million, that allowed 50 per cent of the insects to emerge as adults were as follows: Benzene hexachloride 8, DDT 77, thiourea 81, and borax 924. These concentrations are based on the total amount of media used in each test. The data show that under the conditions of these tests the gamma isomer of benzene hexachloride is the most toxic to housefly larvae of the insecticides tested, DDT and thiourea are approximately equal in toxicity, and borax is the least toxic.—10-3-45.

[1] Courtesy of A. King, of the British Commonwealth Scientific Office, Washington, D. C.

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## Distribution of the Sorghum Midge

EDWARD MCC. CALLAN, *Imperial College of Tropical Agriculture, Trinidad, B.W.I.*

The sorghum midge, *Contarinia sorghicola* (Coq.), is the most important insect known to attack sorghum. It is a well known pest in the U.S.A., where it was first recorded some fifty years ago. In any new country into which it is introduced it is likely to become a serious pest, as has recently occurred in Australia. Resting larvae are able to survive for long periods in seed. The pest can thus be carried great distances and has almost certainly been introduced into new countries in this way.

The bionomics and control of this pest are dealt with among others by Gable *et al.* (1941), Walter (1941), Atherton (1941) and Callan (1941). Walter (*loc. cit.*) states that, in addition to the U.S.A., the sorghum midge has been recorded from Mexico, South America, the Dutch Antilles, Italy, the Anglo-Egyptian Sudan, and also from southern Asia if the species described as *Contarinia caudata* Felt should prove to be the same as *C. sorghicola*.

In this connection it is interesting to note that *Contarinia caudata* causes the same type of injury to sorghum as *C. sorghicola*, has a similar life-history and is attacked by the same parasites. No constant structural differences have been found between these species and, although no breeding experiments have been carried out, it is not unlikely that the two species will prove to be identical. In this case it would appear that the original home of the sorghum

midge was possibly southern Asia, whence it was probably introduced into the U.S.A. in some of the early importations of seeds.

Callan (1941) gives additional records of the sorghum midge from Hawaii and from various West Indian islands, including the U. S. Virgin Islands, Curaçao in the Dutch West Indies and St. Vincent and Trinidad in the British West Indies. It seems reasonable to suppose that this pest was introduced many years ago into both the Pacific and Caribbean areas in importations of seeds from the U.S.A. or southern Asia (?).

In recent years the sorghum midge has greatly increased its range. It is now recorded not only from the U.S.A., Mexico, the West Indies, South America, Hawaii, Italy and southern Asia(?), but also more

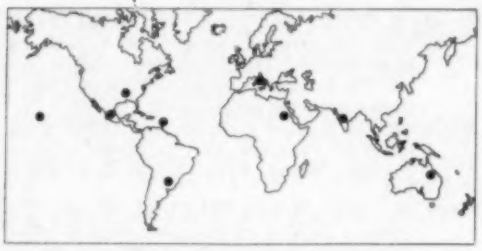

FIG. 1.—Distribution of the sorghum midge, *Contarinia sorghicola* (Coq.)

recently from Africa and Australia. The first records from these continents were from the Anglo-Egyptian Sudan in Africa by Cowland (1936) and from Queensland in Australia by Smith (1939). In both Africa and Australia injury attributed to the sorghum midge was observed several years earlier, so that the introduction of this pest must have occurred some years prior to these dates. In Australia infestation by the sorghum midge has recently been unusually severe, and has given cause for concern in those parts of Queensland where sorghum is extensively grown.

In the Caribbean area this pest is now known from the U. S. Virgin Islands, Curaçao in the Dutch West Indies and St. Vincent, Trinidad, Antigua, St. Kitts and Barbados in the British West Indies. The more recent records are from Trinidad in 1940, Antigua and St. Kitts in 1943 and Barbados in 1944. I am indebted for material to Mr. R. G. Fennah (Antigua and St. Kitts) and Mr. R. W. E. Tucker (Barbados).

The distribution of the sorghum midge extends to all five continents and the Pacific Islands (Fig. 1), so that it has now attained the status of a worldwide pest.—11-27-45.

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## Sabadilla for the Control of the Green Stinkbug

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Considerable damage to developing fruit was being sustained in a 5-acre Palora peach orchard as a result of an infestation of the green stinkbug, *Acrosternum hilaris* (Say). A test was made of sabadilla as a possible means of control. The material used was a commercial dust preparation composed of 10 per cent of *McConnon Sabadilla Concentrate No. 1*, which contains 50 per cent of ground sabadilla seed treated with alkali, and 90 per cent of an inert carrier. The preparation contained 0.1 per cent sabadilla alkaloids.

The dust was first applied to the lower branches of two trees by means of a rotary type hand duster on July 12, 1945. On this date the five nymphal stages were well represented but adults were very scarce. The reactions of a few individuals to the insecticide were observed, all having been well exposed to the dusting. The bugs showed immediate irritation, ceased feeding and began moving aimlessly around, stopping frequently to clean their antennae and rostrum. They progressively lost effective control of their legs, and exuded droplets of clear fluid from the rostrum.

The first bugs fell onto a cloth spread beneath the trees within 10 minutes after the dusting and others continued to drop during the ensuing 52-hour period of observation. Within an hour after treatment, 29 bugs had fallen; 7 more fell during the next 4 hours; 5 others dropped during the succeeding 24 hours, and still another, an adult, fell 52 hours after the dusting. Since the dust was applied only to the lower portions of the trees, the bugs at successively higher elevations would have been exposed to decreasing amounts of dust and this fact may account for the extended period during which the insects dropped.

The bugs that had fallen to the cloth were sometimes able to move about feebly for a short while but sooner or later became moribund. Although they had lost their power of locomotion, many were able to move legs and antennae for a number of hours. Altogether, 42 bugs were collected from the cloths and placed in a shaded tree crotch for several days. None recovered.

On July 14 the entire orchard was dusted with a power duster. Three acres were dusted at a rate of 50 lbs. per acre, while 2 acres received 75 lbs. per acre. The trees were 30 feet or more in height. Twenty-four hours later, on July 15, 19 bugs were counted on cloths placed, before treatment, under 3 of the trees receiving 50 lbs. per acre. These trees were redusted thoroughly on July 16 with a hand duster. After 24 hours, not a single bug had fallen from any of the redusted trees, indicating that the orchard treatment had been effective.

It appears from these results that sabadilla offers excellent promise of controlling the green stinkbug.

## Artificial Shelters for Measuring Densities of *Anopheles quadrimaculatus*

STANLEY J. CARPENTER,[1] *Fourth Service Command Medical Laboratory, Fort McPherson, Georgia*

In order to obtain an index of mosquito abundance, on Army posts in the Fourth Service Command, and to check on the effectiveness of malaria control work, both adult and larval collections are made. Adult collections are of three types: biting, light trap and resting station.

It is often difficult to find satisfactory, well-located, natural resting stations, such as dwellings, stables, privies and culverts on an Army post. To meet the need for diurnal resting stations, where natural shelters are not available, a number of artificial types have been used. Smith (1942) of the Tennessee Valley Authority used nail kegs, and Goodwin (1942) used red boxes in South Georgia for this purpose. On most of our Army posts, where mosquito control work is being done, nail kegs and boxes do not shelter *Anopheles quadrimaculatus* in sufficient numbers to furnish reliable estimates of the adult population.

FIG. 1.—Pyramidal shelter.

Efforts have been made in several Army camps to develop a resting station of simple and cheap construction which would be as attractive to anophelines as natural resting shelters. Two types of artificial shelters have been developed by the Army in the Fourth Service Command which compare favorably with natural shelters.

PYRAMIDAL SHELTER: The pyramidal shelter (Fig. 1) was used during 1943 by mosquito control workers at Myrtle Beach Army Air Field, South Carolina to replace red boxes which were previously used. This artificial shelter is approximately 6 feet high, 4 feet square at the base and 1 foot square at the top. In densely shaded areas all four sides are open for a distance of approximately 30 inches above the ground. For shelters located in partially shaded areas three sides can be closed, leaving an opening on one side for the collector to enter. This shelter should only be used in areas where shade is available. The pyramidal shelter yielded much larger catches at Myrtle Beach Army Air Field during 1943 than red boxes and nail kegs located nearby.

FIG. 2.—Privy-type shelter.

PRIVY-TYPE SHELTER: During 1943 mosquito control workers at Fort Bragg, North Carolina and Fort Benning, Georgia used an artificial resting station in the form of a small house (Fig. 2) in areas where natural shelters were not available. This shelter has the external appearance of an out-door privy and is 4 feet square and 7 feet high. The front is open to a height of approximately 30 inches above the ground to provide an entrance for the collector. A curtain made of burlap or a comparable material should be hung over the opening so as to extend to within 6 or 8 inches of the ground. The curtain may not be necessary for houses located in well-shaded places. Small houses of this type located at Fort Bragg and Fort Benning yielded much larger catches of anophelines than red boxes located in comparable areas.

The author does not feel that the two types of artificial stations described above are superior to well selected natural shelters such as stables, privies and culverts if such are available, but collection records for 1943 have shown them to be far superior to nail kegs or red boxes. Natural shelters, where available, should most certainly be utilized for sampling the adult mosquito population. Small privy-type houses appear to be more satisfactory than pyramidal shelters for measuring densities of *Anopheles quadrimaculatus*.—9-25-45.

[1] Major, Sanitary Corps, U. S. Army.

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## *Phyllocoptes gracilis* and the Dry Berry Disease of the Loganberry[1]

E. P. BREAKEY,[2] *Puyallup, Washington*

For the past several years, the growers of loganberries in western Washington have complained of losses due to a disease which is known to them as the "dry berry" disease of the loganberry. Losses from this disease are so great that the situation has become alarming. In some plantings, these losses are estimated to be as much as 50 to 70 per cent of the crop.

The disease affects the crop early in the season. The blossoms apparently open normally, but instead of the fruits developing in the usual manner, they turn reddish in color soon after the petals are dropped, and soon become brown and dry. As the season advances, some of the fruits escape injury and develop normally. In other words, the fruits from the earliest blossoms are the most severely injured.

Various causes have been advanced for this condition. Perhaps late frosts and infection by parasitic fungi have been most frequently thought of as the possible causes of the disease. However, a critical examination of the then known facts always failed to establish the cause.

Early in June, 1945, the writer's attention was directed to the situation as it occurred on Harstine Island in Mason County, Washington. At this time, the loganberries were in full bloom and fully fifty per cent of the young fruits were obviously affected by the disease. An examination of these fruits disclosed that they were heavily infested with an eriophyid mite. Specimens of these infested fruits were sent to Mr. H. H. Keifer, entomologist with the California Department of Agriculture, under date of June 15. Mr. Keifer identified the mites as belonging to the species *Phyllocoptes gracilis* (Nal.)

This mite has also been identified as a pest of the red raspberry in the Puyallup Valley.[3] Injury to the red raspberry became evident late in the season when affected fruits failed to ripen normally, becoming hardened and somewhat deformed. These superficially resembled the fruits of the Evergreen Blackberry when they have been injured by the mite, *Eriophyes essigi* Hassan, the cause of the "red berry" disease. Apparently, however, *Phyllocoptes gracilis* (Nal.) is a more serious pest of the loganberry than it is of the red raspberry.

Perhaps the mere presence of the mite is not enough to prove that it is the cause of the "dry berry" disease. It can be stated, however, that all known facts support this assumption. Mr. Keifer has apparently reached the same conclusion, for he states:[4]

"The mites which I observed in the loganberries you sent are active in the surface hairs of the green berries, and whenever the opportunity exists they drop down between the druplets causing browning and shriveling of the sides of the druplets. This is apparently the cause of the 'dry berry' disease."

He also states, "I had heard that this mite did a certain amount of damage to the leaves of certain species of *Rubus*, but this fruit damage is something with which I was unacquainted and which has, to the best of my knowledge, not been attributed to the mite."

It is hoped that this mite will yield to the same control measures as those which have been effective in controlling the blackberry mite. Studies on the seasonal history and control of this pest are being initiated.

[1] Published as Scientific Paper No. 637, College of Agriculture and Agricultural Experiment Stations, State College of Washington.

[2] Research Entomologist, Washington Agriculture Experiment Stations. Western Washington Experiment Station, Puyallup, Washington.

[3] Breakey, E. P., *Phyllocoptes gracilis*, A Pest of the Red Raspberry in the Puyallup Valley, JOUR. ECON. ENT. 38: 121, 1944.

[4] Keifer, H. H., In a letter addressed to the writer, dated June, 18, 1945.

## Occurrence of Pacific Coast *Anopheles* in Brackish Water

W. W. FARRAR,[1] *U. S. Public Health Service, Malaria Control in War Areas*

In June, 1944, *Anopheles maculipennis freeborni* Aitken and *Anopheles pseudopunctipennis franciscanus* McCracken, normally fresh water mosquitoes, were found breeding in brackish water at the lower end of Sorrento Valley, 15 miles north of San Diego, California, in a marsh known as Sorrento Wash. This marsh extends inland from the ocean and is heavily overgrown with *Salicornia* for a distance of 1.5 to 2 miles inland.

Analyses of water samples taken from the Wash were made by the U. S. Department of Agriculture Salinity Laboratory at Riverside and it was found that waters from which *Anopheles p. franciscanus* larvae were collected contained chlorides equivalent to 34 per cent sea water (181 milligram equivalents per liter), while those from points where *A. m. freeborni* larvae were collected contained chlorides equivalent to 15 per cent sea water (77.7 m.e./l.). In making these determinations the chloride content of normal sea water was considered to be 535 m.e./1. In these collections *A. franciscanus* larvae were more abundant than those of *A. freeborni*. *Culex tarsalis* was the only culicine mosquito found breeding in the area.

The adaptibility of these anopheline mosquitoes to brackish water was first suspected in August, 1943, when larvae were collected from water reached by high tides along the beach at Santa Barbara by N. F. Hardman and A. F. Geib of the California State Board of Health. However, no water analyses were made at that time. Subsequent to the author's observations, Captain H. N. MacMillen, Post Sanitary Officer at Camp Callan, has found *Anopheles freeborni* and *A. franciscanus* larvae in saline concentrations equivalent to 16 and 32 per cent sea water, respectively, and Ensign W. W. Grafton, Entomologist at the San Diego Navy Hospital, has found *A. franciscanus* in saline concentrations equivalent to 60 per cent sea water.—12-18-45.

[1] Assistant Sanitarian (R).

## The Persistence of Toxicity to Codling Moth Larvae of 4,6-Dinitro-o-cresol Applied as a Tree-Trunk Spray

F. W. CARLSON and M. A. YOTHERS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Heriot (1942) found that a 2 per cent solution of dinitro-o-cresol in a Diesel oil, sprayed on large apple-tree limbs in March, persisted to a considerable extent and killed first-brood codling moth larvae placed on the limbs 100 days after the application and also killed larvae introduced into corrugated paper bands treated 210 days previously.

On March 27, 1943, the writers sprayed blocks of large, rough-barked apple trees with the following formula, developed by Yothers *et al.* (1942, 1943):

| | |
|---|---|
| 4,6-dinitro-o-cresol | 4 pounds |
| Stove oil | 10 gallons |
| Emulsifier: Sodium lauryl sulfate | 4 pounds |
| Penetrant: Ethylene glycol monobutyl ether | 1.5 gallons |
| and trichloroethylene | 1.5 gallons |
| Water to make | 100 gallons |

An average of 3 to 5 gallons of this emulsion was applied per tree by means of a power sprayer. On May 22, 1944, approximately 14 months after the spray was applied, the trees were examined. In addition to some live larvae and a number of dried-up worms that might have died at any time since the spray was applied, there were considerable numbers of dead larvae that were still flaccid. These were evidently overwintering worms that had been killed within the preceding few weeks by material remaining on the trees from the application made in March 1943. Owing to the continuing action of the spray, complicated by the entrance of transforming and overwintering larvae in 1943 and by the emergence of the spring brood of moths in 1943 and 1944, no percentage data could be obtained.

Preliminary chemical analyses and the conspicuous yellowish deposits characteristic of the dinitro-o-cresol on the bark indicated that the compound was still present. The distribution, however, was more uneven than it had been immediately following the application. It was evident that rains and the 8 or 10 sprays applied in the regular schedule had washed some of the material from the more exposed points into places where it was more readily retained.

As Heriot (1942) pointed out, the dinitro compound may kill by contact and also by ingestion. It is possible for mature larvae to get a lethal dose at any time before they pupate—as they crawl over the bark searching for cocooning quarters, as they chew off particles of bark in preparing their cocoons, and, finally, as they chew their way out of their cocoons to prepare their exit tubes.

Apparently the mortality record taken within 2 or 3 weeks after these sprays are applied does not give a complete picture of their effectiveness. Evidently there is a continuing lethal action on the larvae entering the sprayed surfaces for many months after the sprays have been applied.

No injury to the trees has been observed as a result of this persistence of the toxicity in the dinitro compound, even in tree crotches or at the base of the trees in the soil, where the concentration is greatest.

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## Three Years of Orchard Tests of 4,6-Dinitro-o-cresol Against Overwintering Codling Moth Larvae

M. A. YOTHERS and F. W. CARLSON, *U.S.D.A. Agr. Res., Adm., Bureau of Entomology and Plant Quarantine*

Studies of scraping and banding apple trees as a supplementary control measure for the codling moth, conducted by the writers, in the irrigated orchards of the Pacific Northwest from 1935 to 1942, showed that 95 to 100 per cent of the overwintering larvae hibernate on the trees. It was also found that 95 to 98 per cent of these larvae were located on larger branches, scaffold limbs, and tree trunks, mostly above ground but to some extent below the ground level. The remaining 2 to 5 per cent were located on the smaller branches, and in the soil and trash but not against the trees.

In experiments carried on from 1941 to 1944 with sprays to destroy the cocooned larvae (Yothers *et al.* 1942, 1943) the following formula killed 84 to 99 per cent on the sprayed portions of the trees in large and small scale orchard plots:

(Quantities for 100 gallons of spray mixture)

| | |
|---|---|
| 4,6-Dinitro-o-cresol | 4 lbs. |
| Stove oil | 10 gal. |
| Emulsifier: Sodium lauryl sulfate | 4 lb. |
| or *Tergitol* 7[1] | 4 pt. |
| Penetrant: Ethylene glycol monobutyl ether | 1.5 gal. |
| and Trichloroethylene | 1.5 gal. |

**Table 1.—Results obtained with dinitro-o-cresol sprays against overwintering codling moth larvae on apple trees. Yakima, Wash., 1941–44.**

| | Large-Scale Orchard Tests (2 to 4 Acres) | | | Small-Scale Orchard Tests (3 to 5 Trees) | | |
|---|---|---|---|---|---|---|
| Year | Plot | Number of Larvae Examined | Mortality, Per Cent | Plot | Number of Larvae Examined | Mortality, Per Cent |
| 1941 | | | | | 1075 | 94 |
| 1943 | (a) | 356 | 94 | (a) | 456 | 91 |
| | (b) | 728 | 93 | (b) | 163 | 95 |
| | (c) | 1533 | 86 | (c) | 101 | 96 |
| | | | | (d) | 79 | 99 |
| | | | | (e) | 58 | 97 |
| 1944 | (a) | 602 | 84 | | 414 | 85 |
| | (b) | 437 | 93 | | | |
| | (c) | 621 | 95 | | | |

The sprays were applied in March. Two to three weeks later examinations were made of the sprayed larvae on 9 or 10 trees in each plot in the large-scale tests, and 3 to 5 trees in the small-scale tests. The results of these examinations are shown in table 1.

These results indicate that this formula can be relied upon to give a very high percentage of kill of the overwintering codling moth larvae on all parts of the trees where it can be safely applied.

Due to the unavailability of the penetrant materials for the duration a modified formula, from which the penetrant was omitted, was tried in orchard tests in comparison with the foregoing formula. The formula gives a quick-breaking emulsion and contains 3 pounds of DNOC instead of 4, and 15 gallons of oil instead of 10 per 100 gallons of spray. It has given only moderate kill of 56 to 88 per cent.

During 1944 several growers have used this modified formula on several hundred acres of apple and pear trees in the Yakima, Wash., district with results fairly comparable with those obtained in our experiments. Most growers obtained their material as a commercially prepared concentrate.

### LITERATURE CITED

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**Yothers, M. A.**, F. W. Carlson, and C. C. Cassil. 1943. Tests of 4,6-dinitro-o-cresol emulsion against overwintering codling moth larvae. JOUR. ECON. ENT. 36(6): 882–4.

## DDT Sprays and European Red Mite Populations in Eastern New York[1]

R. W. DEAN, *Hudson Valley Fruit Investigations Laboratory, Poughkeepsie, N. Y.*

Numerous investigators have noted increases in European red mite infestations on apple trees sprayed with DDT. After two years' use of DDT in field tests for codling moth and apple maggot control in eastern New York, involving as many as six cover sprays containing DDT, no instance of serious red mite infestation has been observed. Most of these tests were made on the varieties McIntosh and Cortland which, under our conditions, are not considered especially susceptible to red mite attack and, in no case, were red mites numerous when the tests were begun. During the past summer, the effect of DDT sprays on an established red mite infestation has been studied. Six cover sprays containing DDT at the rate of 0.8 lb. of the actual material per 100 gallons were applied to a block of Red Delicious apples in which European red mite were already established. These trees had not been sprayed since before bloom as the crop was frozen out in April, and no oil sprays had been used on them at the dormant or semi-dormant stages. DDT sprays were applied June 6, 18 and 28, July 9, August 7 and 16. Samples of twenty-five leaves from each of four trees were taken at 10-day to 14-day intervals between June 1 and October 15. The mites were removed with a Henderson brusher and counted. The population curves in the DDT-sprayed plat and on unsprayed check trees are shown in figure 1. The populations are shown as percentages of the original populations on June 1, before treatment was started. At that time, there were an average of 32.78 mites per leaf on the sprayed plat and 28.48 mites per leaf on the check.

The similarity of the curves is apparent. In both instances, the mite populations declined in the counts made June 14 but rose to peaks on June 27. The increase was greater on the checks than in the spray plats, 210.19% as compared to 169.28%, but the recession from the peak was more rapid. Both populations reached low levels by August 1. In the checks, this low level was maintained throughout the period of observation but, in the DDT-sprayed plat, there was a later build-up, starting September 3 and culminating in a secondary peak on October 4. This cannot be considered an outbreak since it reached a proportion of only 38.44% of the original population. The difference in numbers of mites at this time is more likely an expression of the relative condition of the foliage in the two plats. In the checks, due to scab infection and previous injury resulting from red mite feeding, the foliage was in much poorer condition than that in the sprayed plat.

Records were made of all red mite predators found on the leaf samples. A total of two, both *Seius* mites, were found in the sprayed plat, and 36, which included thrips, *Stethorus* larvae and *Seius*, in the check. In neither case were they numerous until late in the season, at which time *Seius* became fairly common. It is evident that the decline in numbers of mites following the peak was not due to predaceous enemies or to any other controlling factor which was affected by DDT sprays.

In September of this year, Dr. J. L. Brann Jr., of this laboratory, called the writer's attention to what was apparently a red mite outbreak which developed in an apple orchard being used for a large-scale test of DDT cover sprays. These trees

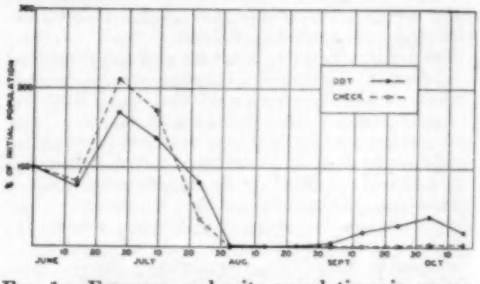


FIG. 1.—European red mite populations in an unsprayed check plat (broken line) and a plat sprayed six times with DDT (solid line), from June 1 to October 15, 1945.

had been examined by the writer on August 21 and found almost free of mites yet, by mid-September, the foliage was badly discolored and mites were present in large numbers. Closer examination revealed that the species involved was *Tetranychus telarius* Linn., the common red spider mite. European red mites, while present, were still few in number.

SUMMARY.—Two years' use of DDT sprays in orchard tests on apples in eastern New York has not yet resulted in increased infestations of the European red mite. The application of six cover sprays containing DDT to a block of Red Delicious trees on

[1] Journal Paper No. 649, New York State Agricultural Experiment Station, Geneva, N. Y., November 27, 1945.

which red mite had already become established did not encourage an undue increase in numbers. In the one instance in which a mite infestation has developed in a DDT-sprayed orchard, the predominant species involved was the common red spider mite.—11-27-45.

## Factors Affecting the Larvicidal Action of DDT on *Culex quinquefasciatus*[1]

H. S. HURLBUT,[2] and RICHARD M. BOHART,[3] *U. S. Naval Medical Research Unit No. 2*

Reports of the use of DDT against the larvae of *Culex quinquefasciatus* in the Pacific Area indicate that larger amounts may be required for the control of this species when it is breeding in foul water than those necessary in other situations. It is well known that *C. quinquefasciatus* tends to show a preference for water with an abundance of decaying organic matter. The data and conclusions presented in this note are based on preliminary laboratory experiments with DDT-xylol-*Triton* emulsion.

The experiments tended to substantiate the observations made in the field, but contrary to expectation, an accelerated kill was observed under certain conditions. Thus, both accelerative and inhibitive effects were demonstrated (Table 1). The accelerative effect is most evident when larvae reared in a medium poor in organic content are tested with DDT in the same medium. The inhibitive effect is seen most clearly when larvae which have been reared in a medium rich in decomposing organic matter are exposed to DDT in the rich medium. However, there is evidence to indicate that an accelerative element is present also in the rich medium since the accelerative effect is seen when a heavy dose (2.5 p.p.m.) of DDT is used in this medium but not when a similar concentration is tested in distilled water. A suggestion as to the nature of the accelerative element was obtained when it was found that certain amino acids gave the accelerative effect with DDT in distilled water. However, this effect was not observed when an amino acid was added to the rich medium with DDT. The accelerative effect was also demonstrated with larvae found in nature when they were tested with DDT in the water in which they were collected. No indication of the nature of the inhibitive element was observed. Both accelerative and inhibitive effects were observed in media having approximately the same pH (8.39–8.70), indicating that pH is probably not a controlling factor.

It is apparent that the amount of DDT required to kill larvae of *Culex quinquefasciatus* varies within rather wide limits according to the conditions under which it is used and this fact will have to be taken into account in practical control procedure.—10-9-45.

[1] The Bureau of Medicine and Surgery of the Navy does not necessarily endorse the views or opinions which are expressed in this paper.
[2] Lt. Comdr., H(S), U.S.N.R.
[3] Lieut., H(S) U.S.N.R.

**Table 1.—Toxicity of emulsified DDT for early fourth instar larvae of *Culex quinquefasciatus* in various media.**

| No.[1] | Rearing Medium | Test Medium[2] | Per Cent Mortality | | | Per Cent Adult Emergence |
|---|---|---|---|---|---|---|
| | | | 6 hrs. | 24 hrs. | 48 hrs. | |
| 1 | poor medium[3] | distilled water; 0.5 p.p.m. DDT | 1 | 81 | 98 | — |
| 2 | poor medium | poor medium; 0.5 p.p.m. DDT | 97 | 100 | — | — |
| 3 | rich medium[4] | distilled water; 0.5 p.p.m. DDT | 4 | 42 | 63 | — |
| 4 | rich medium | rich medium; 0.5 p.p.m. DDT | 8 | 24 | 31 | 66 |
| 5 | rich medium | distilled water; 2.5 p.p.m. DDT | 0[5] | 100 | — | — |
| 6 | rich medium | rich medium; 2.5 p.p.m. DDT | 70 | 95 | 100 | — |
| 7 | collected in nature in clear water | water in which collected; 0.5 p.p.m. DDT | 90 | 95 | no record | — |
| 8 | rich medium | distilled water; 0.5 per cent dl threonine; 0.5 p.p.m. DDT | 95 | 95 | 95 | — |
| 9 | rich medium | rich medium; 0.5 per cent dl threonine; 0.5 p.p.m. DDT | 0 | 35 | 35 | 65 |

[1] Numbers 1 to 4 are averages of 4 tests of 20 larvae each; numbers 5 to 9 are from single tests of 20 larvae each.
[2] Depth 4 cm.; volume 300 cc.; temperature 80°–90° F.
[3] 0.5 gram *Purina Laboratory Chow* per liter, after 4 days in rearing pan at 80°–90° F.
[4] 2.5 grams *Purina Laboratory Chow* per liter, after 4 days in rearing pan at 80°–90° F.
[5] 30 per cent mortality in 12 hours.

## DR. DONALD L. COLLINS

We have not previously noted that Dr. D. L. Collins has accepted a position in the newly constituted New York State Science Service and is now associated with the State Entomologist, Dr. R. D. Glasgow, in the experimental program in entomology in progress at the New York State Museum. Dr. Collins may be addressed in care of the New York State Museum, State Education Building, Albany 1, New York.

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## *The Future of Research*

**Public attention** has been focussed upon the problem of a research program for the nation during recent months to a greater extent, probably, than ever before. The publicity has been largely directed toward the support of a plan, or several plans, for the nationalization of research in order to secure greater support, greater coordination and through these, more prompt results.

Entomologists may not be so much interested as some other groups in this plan but they must not form an impression that their activities will not be included in any overall plan for national coordination and support of research. But, while they are interested in this prospective change in their status, slow as it may be in coming and intangible, often, in the effect which it exerts on the individual, they are concerned also with another development which has been accelerated during recent years, that of commercial support of research programs.

Two courses are open to any interested group, including entomologists. One is to stand by and watch events, acquiescing in the decisions of others, or protesting when it is too late. The other is to keep informed on progress and on plans for progress even before they have matured and been put into execution, and, by individual action and group action, seek to guide progress, not to hinder it, in order that such progress may be, so far as it affects entomology adapted to the needs of entomology. And by the needs of entomology we mean the needs of the people who benefit by the results of entomological research and who, in the long run, must be expected to support such research.

If plans are perfected and put into effect without our knowledge it means that we are asleep or indifferent; if with our knowledge but without any attempt on our part to direct them and cooperate in their development it means that we are neglecting an opportunity and a duty to our profession and our public. If we favor nationalized research we should help promote it and make sure that, so far as it affects entomology, it is wisely conceived and organized; that it has the benefit of the cumulative experience of entomologists working on entomological problems and is not an idealized plan developed by those who have not encountered the difficulties which an entomologist has learned to take for granted.

If entomologists generally feel that research controlled by commercial organizations is unwise, that the results are likely to be unreliable or biased by the desires of those who give their immediate support to the projects, they should make their stand, and their reasons for it, known to all concerned. If the system is unwise it cannot be to the permanent advantage of the interests which support it and they can, by presentation of convincing arguments, be influenced to abandon the system. If it is inherently sound but not properly organized or administered, the same interests can be induced to modify it by the same sort of reasons. Entomologists know that commercial concerns have learned that the only policy which will guarantee long-time prosperity for them is one which seeks to serve the best interests of their customers.

Entomology in industry has been opposed by some because it tends to disperse the research, to create a multiplicity of laboratories and to result in duplication of effort and consequent lack of overall efficiency in the research. But very often the same persons who object to commercial entomology on the grounds stated object just as strenuously to all proposals for the nationalization of research on diametrically opposite grounds. Nothing will reduce our influence as a guiding factor in progress more quickly than such inconsistency. Our position must be con-

sistently conservative or consistently liberal if it is to be extreme.

But it is not inconsistent to favor, with limitations, both trends. The American is an individualist. He objects to undue concentration of power and authority because of the threat that opposes to independent individual action. But, within limits, he favors voluntary cooperation which will tend to promote efficiency. He believes, in other words, in big business. He believes, just as firmly in the right of the individual to conduct a small business enterprise without being smothered by the competition of big business.

We believe that the two types of enterprise can exist in America because both are needed. And that they will continue to exist. And that what is true of business must be true of research which is, after all, the business of manufacturing facts out of a wide variety of raw materials. We believe that a degree of control from some centralized agency may well be needed for efficient attack on many fundamental problems; for effective study of some insect control problems of national scope. We believe that there will still always be need for the pioneering research of the individual; for the informal cooperative research of small groups; for the research of the commercial laboratory, even though that is definitely pointed toward some specific objective. We believe that there is need for all of these *provided* that their objective is never permitted to swerve from the one fundamental of research which is to learn and to teach the truth. The fact that the truth may serve no immediate practical interest does not matter; the fact that it happens to have a definite commercial value does not make it less the truth.

The reason for all this discussion is merely to emphasize the fact that entomologists must keep interested and informed. That they must take an active part in guiding progress or consent to be guided by it. That their role must be active or passive and that, if their role is passive, they will have no standing in the court of public opinion if the course of events does not take the direction they wish.

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# OBITUARIES

## Victor Irving Safro, 1888-1944

Victor Irving Safro was born in New York City on August 26, 1888. He died, a Major in the United States Army Air Force, on May 24, 1944, at Mitchel Field, Long Island, New York as a result of a series of operations. Major Safro was educated in the Public Schools of New York City and attended the New York State College of Agriculture at Cornell University where he was graduated in 1909 with the degree of Bachelor of Science in Agriculture. Just how he came to specialize in entomology, especially since he was city born and bred, I am not quite certain. I believe, however, that his keen mind sensed the possibilities resulting from the study of insects under the stimulus of that great teacher, John Henry Comstock, with whom he naturally had some of his early classes.

Following his graduation he spent a year as Agent and Expert for the United States Bureau of Entomology and was then Assistant Entomologist, 1910–1914, and Assistant Professor of Entomology, 1911–1914, at the Oregon Agricultural College. This included also a period in 1914 as Entomologist of the Hood River Experiment Station of the Oregon State College of Agriculture. He became interested in insecticides and, in the course of this work, published "An investigation of lime-sulfur injury; its causes and prevention." This was an early and important contribution to a more thorough knowledge of this standard insecticide.

In 1914 he joined the forerunner of the present Tobacco By-Products & Chemical Corporation of Louisville, Kentucky, as Entomologist, to undertake the development of nicotine insecticides. His work in this connection was for a long time held up as a pattern to be followed for the development of insecticide uses and had much to do with the later wide acceptance of nicotine as an insecticide. He held this position until 1922, including a leave of absence for military service during World War I.

Victor Safro was undoubtedly one of the first full-time "commercial entomologists" and he quickly became liked and respected by "official entomologists" throughout the United States at a time when it was considered almost a loss of professional prestige for a graduate entomologist to be connected with other than a Federal or State agency or a privately endowed University. Few but the older entomologists can realize to-day the feeling which prevailed in this matter 25 or 30 years ago. Victor Safro, by his sound training, honesty, practical viewpoint and friendly personality, did much to make possible the later acceptance of entomologists employed by manufacturing concerns as respected members of their own profession and of the business world as well.

In 1922, following a desire to have an interest in a business of his own, he became Vice-President and Entomologist of the Nicotine Production Corporation of Clarksville, Tennessee, an established but small producer of nicotine insecticides. He then spent 1924 and 1925 as Entomologist for the American Cyanamid Company of New York City, in

charge of the development of cyanide for the control of insects and rodents. This led to his accepting the position of Chief Entomologist of the California Cyanide Company of Los Angeles. Although the work on the West Coast was enjoyable and profitable to him his residence in the general New York City area became necessary and this was made possible by his being appointed in 1927 to the newly created position of Director of Japanese Beetle Control for the Department of Agriculture of New Jersey with headquarters at the Japanese Beetle Laboratory of the United States Bureau of Entomology at Moorestown, N. J.

Always keenly interested in the development of uses and sales of insecticides and enjoying the somewhat wider personal contacts afforded by the business world, he left the New Jersey Department of Agriculture, after having thoroughly organized the Japanese Beetle Suppression project, to accept an offer in 1929 to develop uses for promising insecticide activators and spreaders then being manufactured by the Kay-Fries Laboratories of New York City. In 1932 he joined the Michigan Alkali Company of New York City to conduct, at first, fumigation research, and remained with this firm, occupying positions of rapidly increasing executive responsibility, until he decided to retire from active business in the fall of 1941.

Following his retirement Victor Safro and his wife made a leisurely trip by automobile to Los Angeles,

VICTOR IRVING SAFRO, 1888–1944

intending possibly to locate in that section, of which they were both fond, or maybe later in Florida. He was on the West Coast when word came of the attack on Pearl Harbor and that night he wired the War Department offering his services, since he was a First Lieutenant in the Air Services Reserves from World War I. The Safros immediately started to head East and word of his appointment came later on while they were at a large family ranch in Central Oregon. He was commissioned a Captain and assigned to the Army Air Force, the effective date of duty being May 24, 1942. Following a period of intensive physical and mental training Captain Safro was assigned to the Middletown Air Service Command at Olmstead Field, Middletown, Pa. Here his unusual administrative abilities soon won the admiration of his Commanding General and earned for him his Majority on August 24, 1943. Major Safro's service record in World War I is as follows: First Sergeant Infantry; Second Lieutenant Air Service; First Lieutenant Air Service Reserves; and First Lieutenant Air Service, Tennessee National Guard.

Major Safro was for many years probably one of the most widely-known entomologists in the United States through his frequent personal contacts with workers in almost every state. His intimate, firsthand and up-to-date knowledge of insect conditions and research activities throughout the country made him a welcome visitor to all, but especially to those who were more restricted in their movements than he. He took great interest in attempting to increase the value and importance of entomology and entomologists in the public economy as well as in the estimation of entomologists themselves. As an aid in bringing this latter about he was responsible for the establishment, in 1937, of the annual Award of Merit of the Eastern Branch of the Association. This has become a coveted honor and has undoubtedly tended definitely to raise the excellence of research and of the presentation of its results.

Safro joined the American Association of Economic Entomologists in 1912 and was active in the Eastern Branch of the Association, being its Chairman in 1938. He was also a member of the Entomological Society of America and, in more recent years, a regular attendant at the meetings of the New York Entomological Society of which he was a member.

The professional or business accomplishments of a man, no matter how outstanding, are not always those for which his life has counted most. Successful and imaginative entomologist and business executive as he surely was, it was for his genial personality his sincerity and his personal helpfulness to so many that Vic Safro was loved and respected and will be remembered by all of us who had the privilege of having him for a friend.

MORTIMER D. LEONARD

## Theodore Henry Frison, 1895-1945

Dr. Theodore Henry Frison, nationally prominent entomologist, naturalist, wildlife enthusiast and conservation administrator, and for the past 15 years, Chief of the Illinois Natural History Survey, died at Urbana, Illinois December 9 at the age of fifty years after a year-long illness. He was born in Champaign, Illinois, January 17, 1895. He was buried in Rose Lawn Cemetery, Champaign, a short distance southwest of the Natural Resources Building which he helped to plan and where he had maintained his headquarters since the summer of 1940.

While attending Champaign High School, Theodore Frison began the study of Entomology under J. W. Folsom, Professor of Entomology at the University of Illinois and a neighbor of the Frisons. Leaving the University of Illinois near the end of his senior year, in April 1918, Frison entered the Army, was commissioned a second lieutenant of infantry in August, and resigned in December of the same year, following the armistice of World War I, to resume his study of entomology at the University of Illinois. There he received his Master's Degree in 1920 and his Doctor of Philosophy Degree in 1923. He was a member of Alpha Sigma Phi social fraternity, Sigma Xi, and the Adelphic Literary Society. He was active in campus orchestras in which he played the violin.

In 1920, after receiving his Master's Degree, he was appointed Assistant State Entomologist of Wisconsin. In 1921-22 he was a member of the staff of the U. S. Bureau of Entomology and Plant Quarantine and was stationed at Moorestown, New Jersey. He was an assistant in the Department of Entomology at the University of Illinois in 1922–23.

Upon receiving his doctorate in 1923 he joined the staff of the Illinois Natural History Survey as Systematic Entomologist. In 1917 the State Laboratory of Natural History and the Office of State Entomologist were merged to form the Illinois Natural History Survey with S. A. Forbes as Chief. Upon Forbes' death in 1930, Frison became acting head of the Survey, and on July 1, 1931, he was named Chief, a position which he held at the time of his death.

By the time Doctor Frison had become Chief of the Natural History Survey he was internationally known for his studies of bumblebees, aphids, and stoneflies, and his correspondents included prominent entomologists throughout the world. Among the more recent publications that helped to place Doctor Frison on the list of internationally known entomologists are: "The Plant Lice, or Aphididae, of Illinois" (with F. C. Holles), 1931, "The Stoneflies, or Plecoptera, of Illinois" published in 1935, and "Studies of North American Plecoptera" published in 1942. Doctor Frison was the author of approximately 100 other scientific and general articles.

Frison was an indefatigable worker with a broad knowledge and appreciation of nature, and a wide-awake and generous administrator. Because of these characteristics and vision, he built up the Illinois Natural History Survey to one of the outstanding biological research organizations in the country. Under his administration, the survey scientific staff was increased from 16 in 1930 to 38 at the time the United States entered World War II. Under his direction the modern laboratories and offices of the Survey in the Natural Resources Building were planned and completed.

Previous to 1934 little research on the once abundant wildlife of Illinois had been done, and many of the so-called conservation measures adopted had failed through inadequate knowledge about birds, mammals, and fishes of the State. Applying scientific research methods to the study of wildlife, Doctor Frison began in 1934 the assembly of a staff of young wildlife technicians that had made significant contributions before it was seriously depleted through calls to the armed forces.

The first meeting of the Midwest Wildlife Conference, held at Urbana in 1935, was largely the result

of Frison's insistence on more and better wildlife research. Field laboratories constructed at Havana and Charleston, Illinois were part of an integrated program of wildlife research he conceived and set in motion. Although highly trained as an insect taxonomist, he inherited from Professors Forbes and Folsom a broad understanding of the entire biological world that gave him perspective in more than one field of science and conservation.

No truer statement could be made than that by Dr. Carl G. Hartman, Head of the Department of Zoology and Physiology of the University of Illinois, as follows: "Doctor Frison was a combination of trained scientist, capable administrator and charming personality. He had the social outlook, and the

THEODORE HENRY FRISON, 1895–1945

interests of the State were his chief concern; yet, he insisted that scientific fact finding be the basis for instituting regulations for fish, game, and other wildlife management. In his personal dealings he was a 'square shooter.' He will be missed for his personal charm and friendliness as well as his professional influence."

Doctor Frison's scientific honors and associations were many. He served as President of the Illinois State Academy of Science in 1941–42. In 1937 he was a representative of the Ecological Society of America on the National Research Council. He had been a Director of the Central States Forestry Congress since 1933 and of the Illinois Audubon Society since 1942. He was Editor of the JOURNAL OF ECONOMIC ENTOMOLOGY from 1936 through 1939, during which time the JOURNAL was modernized and standardized. He was a member of the editorial board of Ecology from 1938 through 1940.

Frison had been on the Advisory Council of the Illinois State Archaeological Society since 1937 and on the Advisory Research Council of the Central States Forest Experimental Station since 1934. He was First Vice-President of the American Association of Economic Entomologists for the year 1945. At various times he served on numerous committees of state and national scientific and conservation organizations.

Doctor Frison was a fellow of the American Association for the Advancement of Science and of the Ecological Society of America, its Vice-President in 1936. Among the organizations of which he was a member are the American Association of Economic Entomologists, the Ecological Society of America, the Illinois Audubon Society, the Society of Wildlife Specialists, the Limnological Society of America, the American Wildlife Institute, the American Society of Naturalists, the Wilderness Society, the Illinois State Florists' Association, the Conservation Council of Illinois, the Illinois Horticultural Society, the Illinois State Nurserymen's Association (honorary), the Illinois State Academy of Science, the Izaak Walton League, the Illinois Federation of Sportsmen's Clubs, and the Chaos Club of Chicago.

Doctor Frison's interest in science did not prevent an appreciation of music and painting, American history and world affairs. The love of music was held over from the years in which he played the violin and perhaps was inherited from his father, well known to early Champaign music lovers as a musician and teacher. World affairs he considered from the viewpoint of the biologist. Regions famous in American history ranked with him in interest second only to the clear streams where stoneflies could be collected and studied.

Ted, as he was affectionately known to his many friends, was married to Ruby Gertrude Dukes in 1919. In addition to his wife, a son, Theodore Henry, Jr., who served with the 99th Infantry Division in Europe, and a daughter, Patricia Ann, survive.

J. J. DAVIS

# PROCEEDINGS OF THE NINETEENTH ANNUAL MEETING

## COTTON STATES BRANCH,
## AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
## Roosevelt Hotel, New Orleans, Louisiana,
## January 24 and 25, 1945.

The nineteenth annual meeting of The Cotton States Branch of The American Association of Economic Entomologists was held in New Orleans, Louisiana, on January 24 and 25, 1945. The meeting was scheduled as The Second Southern War Conference on Entomology, and stress was placed upon Southern war time and post war entomological problems. Over one hundred persons attended the sessions which included representatives from all eleven cotton states.

Chairman E. W. Laake presented an excellent overall discussion of Southern Entomological problems in his address which was entitled, "War problems of Cotton States Entomologists in 1944 and 1945." Dr. Laake based his discussions upon a careful survey of southern entomologists.

President D. L. Van Dine of The American Association of Economic Entomologists appeared formally before those in attendance. He gave a very stimulating talk on the subject, "Some Recollections of a Cotton States Entomologist." Doctor Van Dine also brought to the members of the Branch an overall picture of the National Meeting which was held in New York City in December.

The sessions included symposia on Cotton Insects, Dichloro-Diphenyl-Trichloroethane, post war planning for Southern Entomology, Cooperation Between Southern Entomologists and The Members of the Insecticides Industry, and technical papers.

### BUSINESS PROCEEDINGS

The first business session was held at 5:30 P.M., Wednesday, January 24th. Chairman E. W. Laake was presiding. The following were present:

Adair, H. S.
Alden, C. H.
Anderson, W. E.
Bailey, L. H.
Barber, Ernest
Barber, T. C.
Beck, Wm. D.
Bissell, Theo. L.
Bond, G. L.
Bradley, G. H.
Brunton, Jack G.
Buchanan, William D.
Cartwright, O. L.
Cason, J. A.
Clapp, Alston Sr.
Cole, Moses M.
Collins, R. C.
Colmer, R. P.
Corey, Alvin A.
Criglar, J. L.
Creighton, J. T.
Cuff, Ray L.
Curl, L. F.
Dobrovsky, T. M.
Douglass, N. L.
Dubuisson, E. B.
Dugas, A. L.
Dunavan, David
Dunnam, E. W.
Dutsch, Thos. P.
Dye, H. W.
Eddy, C. O.
English, L. L.
Fenton, Fred A.
Ferguson, F. F.
Ferrell, Ray E.
Forbes, I. L.
Gaines, R. C.
Galloway, A. L.
Garrett, J. B.
Gillaspy, Lt. James E.
Gohmert, W. H.
Gowanloch, James Nelson
Griggs, O. B.
Guice, O. T. Jr.
Harden, Philip A.
Henderson, Chas. F.
Hibbs, E. T.
Hughes, John H.
Ingram, J. W.
Isley, Dwight
Johnson, Howard B.
Johnston, H. G.
Jones, B. B.
Kislanke, J. P.
Laake, E. W.
Lee, J. E.
Lee, Horace W.
Lett, E. R.
Lincoln, Charles
Lindsay, Dale R.
Lipfert, Wm. S.
Loftin, U. C.
Lyle, Clay
McLean, Daniel C.
McNeel, T. E.
Maughan, Douglas
Mecom, W. H.
Milton, Jack
Morrow, J. E.
Nelson, Franklin C.
Nelson, R. H.
O'Brien, C. P.
O'Neille, Kellie
Ogden, Louis J.
Peets, N. D.
Price, R. C.
Prock, Glen
Rebstock, James D.
Reed, W. V.
Roberts, J. H.
Rohwer, G. G.
Rosewall, O. W.
Rowe, W. M. J.
Ruffin, W. A.
Slack, T.
Smith, B. J.
Smith, C. E.
Smith, F. A.
Snyder, Thomas E.
Stanley, W. W.
Stolley, C. H.
Strong, Rudolph G.
Tarzwell, Clarence M.
Tate, Homer
Thompson, Friar M. Jr.
Tingle, Jay P.
Van Dine, D. L.
Van Horn, M. C.
Voorhees, R. K.
White, W. H.

Chairman Laake called for a report of The Secretary-Treasurer. The report follows:

REPORT OF THE SECRETARY-TREASURER.

| | | |
|---|---|---|
| *Funds Received* | | |
| Jan. 26, 1944 | Amount on hand in savings | $121.70 |
| Jan. 26, 1944 | Amount in checking account, Univ. of Fla. | 160.74 |
| May 3, 1944 | Contributions from Industry to cover costs of Stenotypist at Southern War Conference on Entomology | 235.00 |
| July 11, 1944 | 5 copies of proceedings | 6.25 |
| Oct. 24, 1944 | Received from parent organization to cover costs of mimeographing proceedings of Southern War Conference on Entomology | 147.19 |
| Nov. 24, 1944 | Refund of expenses entailed in preparing for Conference | 37.91 |
| Jan. 1, 1945 | Interest on deposit in savings department of First National Bank, Atlanta, Georgia from Jan. 1, 1944 to Jan. 1, 1945 | 1.20 |
| Jan. 17, 1945 | Dues and Registration Fees | |
| | Active Membership | |
| | 1943 dues 2@1.00 | 2.00 |
| | 1944 dues 73@1.00 | 73.00 |
| | 1945 dues 9@1.00 | 9.00 |
| | Registration fees, 1944—24@1.00 | 24.00 |
| | Total Funds Received | $817.99 |
| *Expenditures* | | |
| | Miscellaneous items | 561.33 |
| Balance on Hand Jan. 25, 1945 | | $256.66 |

JOHN T. CREIGHTON
*Secretary-Treasurer*

### APPOINTMENT OF COMMITTEES

Chairman Laake appointed the following committees:

Nominations: F. A. Fenton, *Chairman*
W. E. Anderson
O. W. Rosewall

Resolutions: Theo. L. Bissell, *Chairman*
David Dunavan
W. H. Mecom

Auditing: L. L. English, *Chairman*
W. W. Stanley
Charles Lincoln.

FINAL BUSINESS SESSION

## REPORTS OF COMMITTEES

The report of the Committee on Post-War Planning for Southern Entomology.

## POST-WAR PLANNING COMMITTEE FOR SOUTHERN ENTOMOLOGY

The main purpose of the officers of the Cotton States Branch in appointing this Committee may be stated as follows: That the consideration of suggestions and plans, developed in the attempt to look ahead to the peacetime years, should so stimulate our thinking that we shall be in position to better serve the southern states and thereby contribute to the welfare of the nation as a whole.

A report on post-war planning may be termed by some as theorizing about peace, and others may claim that such planning is out of order at the present time. But if we expect to grasp the opportunities that will enable us to be of greater service in providing protection against diseases and losses caused by insects, we must begin now to formulate our programs with the following objectives in view:

(1) For continuing in the future those entomological activities which have contributed so much to the war effort: (2) For support and expansion of other entomological activities to meet the extra requirements demanded by a rapidly changing world, and, (3) For meeting new and altogether different problems, some of which we can already recognize.

Your Committee, like that of the Post-War Planning Committee of the American Association, "has no authority and no responsibility to translate into action any program" which may be suggested or outlined at this time.

By giving carefully considered thought to the needs of the present, the sub-committees have endeavored to appraise the future possibilities from an entomological viewpoint with reference to the activities discussed in the following papers.

## REPORT OF SUBCOMMITTEE ON TEACHING, TAXONOMY, AND MUSEUM

The First lectures in Entomology in the Southern States were given fifty-five years ago. During the elapsed fifty-five year period progress has been made in this educational field. Yet, today southern entomological instruction constitutes a rather pioneer field in the educational world.

Today the educational field of entomology occupies an unusual position. Under normal conditions the Southern teacher of entomology has such an extremely heavy clock hour and student hour load that he finds little time for research, or for a study of methods of instructional improvement.

The present world conflict has curtailed instructional activities in all fields and entomology has felt the impact. The reduced student enrollment offers a challenge to the teachers of entomology, as it has brought about the greatest lull that has occurred in the instructional branch of the science since its inception.

This period should be used in an effort to improve and advance our departments of entomology; and thereby assure stronger instructional entomology in the post-war period.

Inasmuch as possible teachers must discourage any diversionary efforts that would take them too far away from the principal objective of advancing entomological science along the educational front. All Southern entomologists should aid in attaining the objective by free discussions of deficiencies, and by conscientious efforts to obtain improvements.

POST-WAR PERIOD.—In the post-war period we will be concerned with three types of instruction; namely, the training of returning veterans, training on the undergraduate level, and training on the graduate level.

TRAINING OF VETERANS.—During the remainder of the war and in the post-war period Southern educational institutions will have a gradual influx of student veterans, that will reach enrollment heights one to two years after cessation of war activities.

*Entomological Training.*—Many of these returning veterans will desire special training in certain phases of entomology that will result in desirable employment. This interest in entomology will be due in great part to the direct or indirect contacts that these young men are having with insects during the course of the world conflict.

The teachers should plan now for the proper training of all such individuals. Special curricula should be formulated that will give them a broad practical training and thereby qualify them for immediate employment following the completion of the curriculum.

*Training Standards.*—The returning veterans will consist of two types; namely those who are conscientiously seeking valuable training, and those merely attending school during an interim period at Government expense. Teachers must appreciate the effects that the severe impact of war has had upon these young men. They should be sympathetic and helpful wherever possible. However, they should be realistic enough to avoid rendering these young men a disservice by abolishing scholastic standards and permitting a flood of improperly trained individuals to flow into the channels of entomology.

The greatest service that can be rendered these young men is to encourage a realizations of the need for a practical approach to their future which demands thorough basic training.

UNDERGRADUATE TRAINING.—An appraisal of educational methods and results on the undergraduate and graduate levels is justifiable. Changes and adjustments will likely occur.

In such an appraisal of undergraduate instruction consideration might be given the following.—

*General Entomology, Insect Morphology and Physiology, and Insect Ecology.*—Courses in these subjects embrace some of the most essential material that is covered in undergraduate courses. These can be strengthened if more emphasis is placed upon the applied aspects of entomology. Teachers should endeavor to use insect species of economic importance in presenting these subjects. Students would then have a greater appreciation of the importance of entomology.

*Emphasis on Agricultural Subjects.*—Entomology makes some of its greatest contributions in the field of agriculture. Therefore, any student who contemplates entry into the field of Agricultural Entomology should be well grounded in scientific agriculture. This should include strong courses in all technical agricultural fields.

In turn every student pursuing agricultural work in southern institutions should be required to take a course in General Entomology and one or more courses in some economic phase of the subject.

The entomology graduate should also have a broad knowledge of farming operations if he is expected to be readily accepted by farm operators. This seems to be a very glaring weakness in the average graduate.

*Practical Experience.*—The need for practical experience is always evident. Student assistants and Research assistants in departments of entomology frequently gain experience that is invaluable in their future activities. All students, seeking the Bachelor of Science Degree in Entomology, need a period of practical experience during their college days or after graduating before they are certified for permanent employment in the field of entomology.

*Two Types of Students.*—Many students who pursue course work in entomology do not plan to follow the subject as a profession. The appreciation that these students have for the importance of entomology may have fundamental effects upon the advancement of the science.

Therefore due regard should be given to the presentation of courses for such students. These courses should be informative while serving as a stimulating influence upon this important group. This can be done without a reduction in the standards that may be established for training professional entomologists.

*Training of Vocational Agricultural Students.*—The vocational agricultural student constitutes one segment of the above group. It is important that these young men be well trained in the fundamental principles underlying the control recommendations that are made. This will enable them to make more logical appraisals of changes that may periodically occur in control procedures.

*Broadness of Training.*—The modern entomological educator is similar to the early educator in his insistence upon a broad basic training for entomology students. The entomology graduate must be well trained in the zoological and botanical sciences, he should be well trained in the agricultural sciences, and consideration should be given to all other phases of science.

Finally he should have broad training in all fields that will facilitate ready adjustment in his social as well as professional niche after graduation.

*Specialization.*—Extreme specialization of subject material constitutes one of the most profound developments in entomology. This necessitates certain specialized training for those planning to enter the following fields: Teaching, Research, Extension, Apiculture, Plant Quarantine (Legal Entomology), Forest Entomology, Industrial Entomology, Structural Pest Control and Medical and Veterinary Entomology.

It is doubtful if many of these specialized fields have been given due consideration by educational departments in the southern states. For example the present war has revealed striking deficiencies in the training for Medical Entomology. Even those students having course work in Medical Entomology were usually found to be inadequately trained in the actual identification of important disease vector groups.

In the post-war period such fields as plant quarantine, Medical and Veterinary Entomology, Industrial Entomology, and Structural Pest Control will require the services of many of our graduates. Every effort should be made to assure the proper training of such individuals.

*Speaking and Writing.*—The southern entomological graduate of the future should be one well trained in writing and public speaking. These constitute two of the most glaring weaknesses in our graduates. Such weaknesses are too frequently revealed in submitted reports and public appearances.

*Organization and Administration.*—The field of entomology includes projects which have tremendous appropriations. Many excellent entomologists have failed at the height of their careers because of a lack of training in organization and administration; as well as an inability to understand the public and the political institutions with which they are associated. Training along these lines would definitely benefit those entomologists who plan to go into quarantine, large scale control projects, industrial entomology or structural pest control.

*Visual Instruction and Exhibits.*—Visual instruction does not supplant the need for field contact with materials and problems. However, it is an essential modern accessory method of instruction. Every department should attempt to build up a worthy movie, film strip, and slide library. Free exchange relationships should exist between every department in the south. This will broaden the service of such instructional methods.

Each institution should endeavor to maintain worthwhile exhibits of destructive insect species that are important to agriculture as well as to the health of the citizenry. These should be made available to all worthy groups for demonstration purposes.

*Size vs. Efficiency.*—Entomology departments have increased in size in nearly every Southern institution. This increase has included physical set-up, personnel, and student enrollment. However, appreciation of the importance of this field of endeavor has not reached proper heights. The present war has intensified the public acceptance of its importance. We must make every effort to bring proper administrative attention upon the needs of educational departments in order that facilities may be provided that will assure worthy advancement in the post-war period.

Those states that do not have a separate Department of Entomology in their state college or university should be encouraged to make the necessary provision for the creation of such a department.

GRADUATE TRAINING.—The conditions that exist in the South are conducive to the advancement of entomological training on the graduate level. The plant flora and fauna are abundant and this results in a diversity of entomological problems. The South is a great agricultural area and there is no single factor that has a greater effect upon agriculture than insects. They are also important in their relationship to the health of our citizenry.

The weather in many southern states is conducive to field research in entomology throughout the year. Such factors should immediately focus attention upon the need for development of instructional work on the graduate level.

We seem prone to continue accepting an inferior position in the educational world. In some instances such an inferiority is more imaginative than factual. The physical set-up and personnel in many southern departments is superior to that possessed by some of the so-called "leading departments" when these departments entered the advanced degree field.

If advanced degree work in entomology is to be a success in the south we must incorporate the following in our advancement platform:

1. Encourage potentially strong graduate material to continue their training at suitable southern institutions.

2. Discourage whatever tendency that may exist relative to recommending the weaker graduates for assistantship, fellowship, or scholarship vacancies in departments of southern institutions.

3. Encourage all employment agencies to give first or equal consideration to southern trained men for positions on southern projects.

4. Encourage the offering of advanced degrees in those departments and institutions where it is feasible.

5. Institute a desirable publicity campaign on the value of graduate work to the agricultural and social advancement of the South.

6. Encourage the establishment in our universities and colleges of commercial and other types of scholarships and fellowships.

7. Establish an employment committee; this committee to act as a clearing house for releasing information relative to vacancies.

8. Encourage all administrative officers to effect a re-alignment in pay between the southern trained employee and those trained in other areas.

9. Encourage the development of a standardized method of pay increase in southern institutions.

10. Encourage capable teachers to remain in the South.

TAXONOMY AND MUSEUM.—The southern states have not made the proper progress in the field of scientific collections. This has been due in part to the small overworked personnel in each state and a lack of storage facilities. Every effort should be made to correct these weaknesses in the early part of the post-war period.

*Taxonomists.*—The need for taxonomists during the present world conflict has attracted some attention to the great needs in this field. Taxonomists that have been employed in war service or developed by war agencies will need employment after the cessation of the conflict. Efforts should be made to provide for them.

Taxonomy has been neglected. Its importance in the future will be enhanced because of the possibility of insect introductions. Educational departments should provide for a more thorough training of students in the field of identification and museum methods.

*State Collections.*—Each state should begin the development of a permanent collection of insects with an ultimate aim of having a complete collection of all insects occurring within the state. At least one full time taxonomist and one or more aides should be employed. Such work might be of a cooperative nature between the Experiment Station, the College of Agriculture, the State Department of Agriculture and the State Quarantine enforcement agency. Support for such work should be of a permanent nature. Careful insect surveys should be made in all state regions.

Intimate contacts between such representatives in all southern states and those in Central and South American countries should be maintained in order that valuable interchanges of thoughts and materials might be encouraged.

*National Collections.*—In our zealous efforts to advance our southern states in the fields of taxonomy and museums we must not fail to recognize the many advantages inherent in a well developed centralized national museum. Encouragement should be given to a more extensive subsidization of insect taxonomy and museums by the Federal Government. This museum should eventually supply full identification service, and where feasible correctly identified specimens for reference use for a nominal sum.

This sub-committee, is of the opinion that the progress in the fields of educational entomology, taxonomy, and museum will greatly influence the sound advancement of all entomological fields in the southern region.

H. S. ADAIR, H. G. JOHNSTON, W. WHITCOMB, JR.
F. A. FENTON, CLAY LYLE, JOHN T. CREIGHTON, *Chairman*
A. D. HESS, C. E. SMITH

## SUBCOMMITTEE ON QUARANTINE

In submitting this report to the Chairman of the Post-War Planning Committee, the Sub-Committee on Quarantine has treated the subject under two headings: Domestic Plant Quarantines and Foreign Plant Quarantines.

DOMESTIC PLANT QUARANTINES. (A) *Realistic Approach Relative to Enforcement of Domestic Plant Quarantines.*—It should be recognized that at the present time there are numerous difficulties that make quarantine enforcement a very complex field of work. It should also be recognized that many more difficulties will arise in the post-war period which will make the field of Domestic Plant Quarantine enforcement more complex.

A strengthening of quarantine and inspection activities in the southern region due to the increase of both imports and exports, especially as a result of air travel, is most desirable.

A definite contribution could be made to the field of quarantine enforcement by bringing to the attention of all concerned the many difficulties that are now involved in enforcing Domestic Quarantines and in making a careful appraisal of those things that can be done to bolster the effectiveness of our quarantines.

TRADE BARRIER QUARANTINES.—An unbiased study of all Domestic Plant Quarantines in the South-Southwest should be made to determine if any of the quarantines in force constitute unreasonable trade barriers. If such a condition were found to exist, action should be taken to bring such cases to the attention of the proper remedial agencies.

UNIFORMITY OF STATE QUARANTINES.—There has been and will continue to be an urgent need for uniform State regulations concerning plant quarantine and inspection laws. There should be a constant effort to standardize the permit tags of the various states.

EMPLOYMENT OF QUARANTINE WORKERS.—Inasmuch as the post-war period may see large scale control and eradication projects by State and Federal agencies and such projects, in most instances, would have to be tied in with the enforcement of quarantine regulations, it would be most desirable if technically trained personnel could be employed by the various quarantine services as a means of improving the quality of quarantine work.

WIDESPREAD INTEREST IN QUARANTINE WORK.—It would be most desirable if all the entomologists of this group, regardless of the particular field in which they are engaged, were acquainted with the plant quarantine problems and ready to assist with their suggestions and helpful influence in bringing about desirable actions. For example, the pink bollworm threat at present should be a matter of concern to every entomologist and not just those charged with plant quarantine work.

FOREIGN PLANT QUARANTINE.—Increased support for the Division of Foreign Plant Quarantine in the Bureau of Entomology and Plant Quarantine on account of the development of many new problems due to the war should be a matter of general concern to this group. It is recognized that the problem involved in the enforcement of foreign quarantines

will be greatly increased in the post-war period. To combat these problems we should all strive for greater Federal appropriations to provide adequate well-trained personnel to conduct this work in the post-war period.

QUARANTINE INFORMATION.—There is a great need for quarantine information in a condition satisfactory for assimilation by quarantine enforcement workers. This information should pertain to American quarantines as well as those of foreign countries. Publications relative to quarantine should be increased.

MEMBERSHIP IN SCIENTIFIC SOCIETIES.—Quarantine workers should become affiliated with scientific groups and maintain such affiliation.

JOHN T. CREIGHTON OLIVER I. SNAPP
CLAY LYLE O. B. GRIGGS, *Chairman*

## SUB-COMMITTEE ON SOUTHERN EXTENSION ENTOMOLOGY

Each member of this sub-committee has generously contributed ideas and suggestions that have been incorporated into this report.

It is apparent, to anyone who has given the subject careful consideration that the Extension Service could be, and by all means should be, one of the most important factors in the future development of practical insect control throughout the Southern States. The Extension Service, because of the very nature of its organization, is in a position not only to widely distribute information concerning the control of insect pests, but to actually demonstrate to farmers that insect control is both practical and profitable. A large percentage of our farmers are not yet convinced that insect control in general is practical and many think that it is too expensive. In reality insect control methods, if properly conducted, do not cost money but pay dividends. Thus the major factor in the future development of a widespread insect pest control program is a problem of public education.

This is well illustrated by a statement recently released by Dr. Annand that an estimated 150 million dollars are spent each year by Federal, State and private agencies in an attempt to prevent damage from about 70 of our more destructive insect pests in the United States, yet these same pests cause losses amounting to more than 1½ billion dollars annually. Much of the loss attributed to any one of these pests *can be prevented* if available control measures are applied generally throughout an infested area at the right time and in the right way. For the most part these losses can be prevented only by the farmer himself and he must be thoroughly convinced that insect control should be made a definite part of his production program, and should be given just as careful attention as soil preparation, planting, cultivating, and harvesting.

The Extension Service as a whole has developed rapidly during the last twenty years but extension entomology, has not kept pace with the rapid strides made by entomological research. It is rather interesting to note that it was an entomological problem, the control of the cotton boll weevil, that led the way for the development of the National Extension Service and yet extension entomology has been the most seriously neglected branch of this organization, particularly in the Southern States. It has recently been pointed out that of a total of 1690 extension specialists in the United States only 50 are entomologists. The percentage of entomologists in the Southern States is even lower than this figure would indicate, and this ratio is entirely out of proportion to the relative importance of the subjects involved. Only two states in the South, I believe, have more than one extension entomologist, and several states have none.

Insect control problems have been greatly emphasized during the last three years in connection with the war production programs and tremendous interest has been developed among the farmers of the South. Every effort possible should be made in the post-war years to maintain this interest and take advantage of the opportunity to greatly expand extension entomological work. In order to do so there are many important factors that must be given particular attention. Some of the more important ones will be listed here.

1. The first and by far the most important requirement is to have at least one, and in most cases several, adequately trained extension entomologists in each state. No more effective method has been found to teach farmers how to control insect pests than the use of definitely controlled method and result demonstrations. These demonstrations must be closely supervised by the County Agent under the supervision of the extension entomologist. All programs must be carefully planned in detail and presented to the County Agent in such a way that it will require a minimum of his time and effort. This must be followed up during the growing season with field meetings and inspection tours so that the greatest number of people possible may be benefited by these demonstrations. Furthermore, considerable time will be required for state, district, and smaller group meetings with County and Home Agents to familiarize them with the program that he has planned and to inform them of new developments in methods of insect control. Consequently one Extension Entomologist cannot adequately handle all entomological problems over a very large territory.

2. Another very important factor is adequate entomological training for County and Home Agents. Many County Agents and practically all Home Agents have had no entomological training. Still all extension insect control problems must be supervised in part at least by these Agents. It must be kept in mind, however, that County and Home Agents cannot be expected to be well trained entomologists. Their duties are many and varied and consequently their training must be general. Every County and Home Agent, though, should have a thorough basic knowledge of the structure, habits, development, and methods of control of insects in general. All agricultural and Home Economics Schools should offer general courses devoted largely to practical or applied entomology for students who do not expect to become trained entomologists. In the final analsyis the Extension Entomologist will probably have most of the responsibility for training County and Home Agents in methods of insect control. This can be done through field demonstrations that the agents must supervise, annual short courses, district and sub-district meetings, and individual contacts.

3. Among the many farm organizations through which the Extension Entomologist and County and Home Agents can carry information to farm families the 4-H Clubs are perhaps most important. These boys and girls are much more interested in methods of insect control and other recent advances in agricultural methods than most adult farmers are. Furthermore it is usually much easier to get a farmer interested in a new project by working with his son than it is to work directly with him. At any

rate these 4-H Club boys and girls will be the farmers and housewives of tomorrow and the training and experience that they gain from insect control demonstrations will be most valuable in the future. With a little training and supervision many of these boys and girls will do an excellent job on insect control projects. It has been definitely demonstrated during the last two years that 4-H Club boys can do an excellent job of reporting cotton insect populations for survey purposes. Since the economical control of cotton insect pests must be based upon the population of pests in individual fields, then this sort of project could be definitely combined with control demonstrations. 4-H Club members have also carried on successful demonstrations for the control of cattle grubs, poultry lice, garden insects and others. There is no doubt that this field of demonstration work should be greatly expanded.

4. Since insect control problems affect, either directly or indirectly, almost every branch of agricultural production, the Extension Entomologist must maintain the closest cooperation possible with other extension specialists. The Agronomist, the Horticulturist, the Animal Husbandman and others should take into consideration cultural practices such as soil preparation, varieties, rotations, time of planting, proper pruning, destruction of crop residues, and ranch practices that will prevent insect damage as far as possible. Unless such cooperation is maintained then insect control becomes primarily a salvage program after conditions have been made favorable for their development and serious outbreaks result.

5. Methods of presenting subject matter by the Extension Entomologist as well as County and Home Agents can be greatly improved. Colored slides and movies can be used to excellent advantage in many ways. A complete series of slides should be developed for all the major insect pests occurring in the area concerned. These slides should show the developmental stages of the insect, the nature and extent of its damage, and the method and results of proper control measures. Such a series of slides can be used for many different purposes by extension workers as well as commercial dealers. One unusual and interesting use of such slides was reported by a member of this Committee. A large seed dealer in Louisiana maintains a series of slides on insect pests in his area arranged by crops. When a grower comes to his store with a complaint concerning insect pests the dealer shows him these slides with a projector and determines exactly the pest involved. He is then in position to make specific recommendations for control. Such a use would be valuable for County and Home Agents in addition to using them for many of their meetings. Colored slides have many advantages over movies for general purposes, although movies have a definite place in this type of teaching.

6. It is generally recognized by both professional entomologists and members of industry that closer cooperation on problems of pest control is essential. There is no doubt that such programs as this will do much to create a better understanding of each others' problems and ultimately lead to their solution. From the Extension Entomologists' viewpoint perhaps the most important problem is the proper distribution of insecticides. Too often his recommendations are not carried out by the grower because he was unable to obtain the insecticide recommended. This can be overcome by the entomologist to some extent at least by obtaining from the wholesale dealers in any area a complete list of the insecticides handled and furnish each County Agent in the State a copy of this list. The Agent can then inform his local dealer who is usually a seed dealer, feed dealer or druggist, concerning the principal insecticides that he expects to recommend in the County and furnish him with a list of dealers from whom they may be obtained. The entomologist must be fair and impartial in making his list and the dealer must cooperate by furnishing this list to prevent discrimination. Most manufacturers and many dealers have been very cooperative in furnishing extension workers with materials for demonstration purposes. In some cases this privilege has been abused by extension workers by requesting more material than was needed or using materials for purposes other than was intended. It is also important that in the formulation of insecticides for sale to growers the manufacturer should conform as closely as possible to State recommendations. Such cooperation will be mutually beneficial.

7. Beekeeping is more or less a separate and distinct program for the Extension Entomologist. This program has received considerable emphasis during the last few years because of the importance of bees wax in war production, as well as increased honey production. The increasing emphasis on legume crops for seed production, for soil improvement, and pasture improvement is increasing the interest in honeybees as pollinators for these crops. The basic need for the expansion of this program, as for pest control, is a better understanding of the problems concerned among the farmers who must deal with these problems. Therefore beekeeping should be included along with the educational program for pest control.

In conclusion we believe it is evident that the educational program for insect pest control should be greatly expanded in the post-war years. In order to do so a greater number of adequately trained Extension Entomologists will be needed in the Southern States. Better training in Entomology will be necessary for County and Home Agents, and the Extension Entomologists will need the whole-hearted cooperation of all other agencies interested in agricultural production.

ALSTON CLAPP SR. HORACE W. LEE
W. WHITCOMB, JR. CLAY LYLE
C. E. SMITH OLIVER I. SNAPP
H. G. JOHNSTON, *Chairman*

## SUBCOMMITTEE ON LARGE SCALE PROJECTS (PESTS OF GARDEN AND ORCHARD CROPS)

LARGE SCALE PROJECTS FOR CONSIDERATION.—The five-year period immediately after the combat phase of the war against organized armies ends, will undoubtedly usher in large scale control and partial eradication projects by State and Federal agencies of some of our more economic garden and orchard pests. More effective insecticides and improvements in machinery will surely contribute to the adoption of these projects. The Cotton States Entomologists must be prepared for such an eventuality.

A great deal of stress will be placed on quality products after the war, and of course, this will include vegetables and fruit crops. The new processing methods, such as quick-freezing, dehydration and others, will tend to increase the demand for blemish-free products. This will call for a general program on the control of vegetable and fruit insects.

The control or eradication of the sweet potato weevil is a large scale project for consideration in plans for post-war entomology. Work is now in progress

on this project, but it can be extended to additional areas and enlarged in the areas being worked at this time. The control of the Oriental fruit moth is a project of large scale proportions, and plans for this project should emphasize biological control. The control of the codling moth is one of national proportion and the setup for a large scale project should include all apple producing areas in the country. The development of the ethylene dichloride and propylene dichloride treatments for peachtree borer control makes possible a large scale project with this insect. The degree of peachtree borer control from these insecticides is such that control and perhaps elimination of this insect in large areas is possible as a result of a large scale project of several years' duration.

Tomatoes are grown extensively in the South and suffer considerable damage from the tomato fruit worm. The crop is grown in such scattered areas that it may not lend itself to a large scale project for tomato fruit worm control. However, during the post-war period this crop will likely receive considerable attention in the states where it is grown commercially, and a large scale project on tomato fruit worm control should be considered.

DIRECTION OF LARGE SCALE PROJECTS.—Highly trained men who have demonstrated their administrative ability should direct the large scale projects in the post-war period. This is necessary for public confidence and will result in better contributions.

*Preliminary Studies.*—To provide for large scale projects in addition to those suggested for consideration, preliminary studies should be made now of those pests in the agricultural complex which would best submit to such concentrated control efforts, and thereby prove of greatest economic and social value.

*Tests With New Materials.*—Many new materials for insect pest control have appeared recently and will continue to appear during the post-war period. The phytocidal effect of these materials on hosts must be known and insect toxicological tests will be required. Some of these tests with new chemicals should logically be conducted now to serve as a guide in outlining large scale post-war control projects.

*Effect of Toxic Agents on Beneficial Insects.*—The effect of new materials on parasites and predators will have to be determined before these chemicals can be included in the program of a large scale project for insect pest control. Careful consideration should be given now to the effect of new insecticides upon the biological complex, especially parasites and predators.

*Preventive Entomology.*—It is believed that we should do more in the way of preventive entomology. For example, by the use of bait pails in apple orchards, advise orchardists as to the correct dates for applying codling moth sprays. It may be possible to devise a means of predicting what the pecan nut case-bearer may be in a large area by making examinations of representative pecan groves throughout the area in order to determine the percentage of bored terminals. Electric light traps might be utilized to determine the appearance and abundance of certain insect species. The prediction of the appearance in destructive numbers of certain well known pests so that proper measures for their suppression may be taken by growers and orchardists themselves is the object of these suggestions. In areas where there are a large number of orchards or where truck farming is the principle business, the most good could be accomplished by placing in each area an observer whose duty would be to take frequent samples on representative farms and issue periodic current information on pest control. We should know in advance what to expect in the way of insect outbreaks, rather than having to wait until they develop.

JOHN T. CREIGHTON C. E. SMITH
F. A. FENTON OLIVER I. SNAPP, *Chairman*

## SUBCOMMITTEE ON EMPLOYMENT

The following recommendations are made concerning the policies and actions of the Cotton States Branch with reference to post-war planning for the employment of entomologists:

RE-EMPLOYMENT OF RETURNING VETERANS.—In accordance with the "G.I. Bill of Rights," all entomologists returning from military service should be given re-employment, even though it means releasing persons who have substituted for them during the war period. However, it should be kept in mind that these substitutes have in the large part been providing services of critical importance to the war effort, and full consideration should be given to their post-war employment needs. Particular attention should be given to protecting those with sound entomological training and experience from suffering in competition with individuals who have had only a fleeting acquaintance with entomology through a temporary detail to such work.

FULLER UTILIZATION OF ENTOMOLOGISTS.—Efforts should be made to encourage and promote the development of desirable post-war projects offering employment for entomologists; and to encourage and promote the fuller utilization of professional entomologists in agriculture, industry, teaching, and research. Among the possibilities may be listed the following:

A. More extensive utilization of measures for the control of agricultural insect pests and insects affecting the health of man and domestic animals.
B. The establishment of more laboratories for research in economic entomology and the intensification of research on regional problems in insect control.
C. Increasing the amount of entomological extension services provided by states and counties.
D. Providing more and better entomological training in state colleges and universities and adding new courses in applied entomology such as entomological engineering, veterinary entomology, commercial entomology, and medical entomology. Decreasing "teaching loads" in order to improve the quality of entomological training.
E. Government subsidization and expansion of work on the taxonomy of insects, particularly in state and national museums.
F. The establishment of more large scale state and federal insect control projects, such as the malaria control programs of the Tennessee Valley Authority and Malaria Control in War Areas.
G. The fuller utilization of professional entomologists by state and county health departments, insecticide companies, pest control operators, etc.
H. The establishment of legislation requiring the licensing and proper entomological training of individuals doing insect control work, particu-

larly with reference to the use of insecticidal materials such as DDT.

UNIFORM STANDARDS.—Uniform standards of training and experience should be established as qualifications for entomological employment at various professional levels. This is an extremely important task and deserves the most careful consideration of fully qualified individuals from the various fields of entomology. The establishment of such standards would lead to better entomological training in colleges and universities. Attention should also be given to the establishment of minimum salaries for the various professional grades. The word "entomologist" should be given more significance with reference to entomological training and experience and membership in entomological societies.

EMPLOYMENT SERVICE FOR ENTOMOLOGISTS.—The Cotton States Branch of the American Association of Economic Entomologists should provide an employment service to assist worthy entomologists in finding employment and to help employers of entomologists in locating suitable personnel. The office of the Branch Secretary might well be used for providing this placement service.

H. S. ADAIR JOHN T. CREIGHTON
G. H. BRADLEY HORACE W. LEE
O. B. GRIGGS A. D. HESS, *Chairman*

## SUBCOMMITTEE ON RESEARCH

THE TESTING OF INSECTICIDES.—Recent trends are for the laboratory testing of the effect of insecticides on insects on a much more exact scale than hitherto thought possible. Equipment for this purpose should be available for testing new insecticides which have been discovered or developed during the war as well as those now in use against both injurious and beneficial insects. As the second step in this work, facilities should also be available for testing promising compounds in small plots or plantings especially to determine the phytotoxicity and effect of weathering upon insecticides.

There is need for greater use of approved experimental technique in planning factorial experiments, sampling the plots and evaluating data by methods of statistical analysis.

Participation with reliable manufacturers is desirable. This familiarizes the research staff with problems of pest control in industry and it provides funds for expansion of research.

COOPERATION BETWEEN FEDERAL AND STATE LABORATORIES.—Coordination of federal and state laboratories in testing methods and planning work programs is desirable. The federal laboratory has the advantage of equipment, adequate personnel and labor which the state experiment station often lacks. There is also no diversion in teaching and extension so that intensive work can be done. The federal laboratory is not restricted by state lines so that a broader picture of the problem can be obtained.

The state experiment station is more familiar with state problems, is in a better position to formulate specific recommendations, is better able to get out timely information, has access to better library facilities and has better contact with allied fields of research. By combining the advantages of both, entomological research can be greatly advanced.

FUNDAMENTAL BIOLOGICAL RESEARCH.—There is a great need for more fundamental biological research. The study of insect pest species under controlled conditions, when possible, is often productive of far reaching results. Facilities for controlling temperature and humidity in laboratory cabinets are necessary in this type of work. The insect species should also be investigated in its natural habitat to determine its reactions to food conditions, weather, competitors, natural enemies, etc.

INSECT PEST PROBLEM IN A CHANGED SOUTHERN AGRICULTURAL ECONOMY.—*Cotton production.*—Competition with other fabrics will inevitably restrict cotton production to the best soils which will produce the best grade of lint in the east, accelerate large scale productive methods of cotton growing in the west, and give greater emphasis to the production of cotton for its oil and other byproducts. This will result in a demand for greater emphasis on intensive insect pest control in the east, and for the development of large scale control methods such as airplane dusting in the west. The boll weevil continues to be our most serious problem but we should not be content with our present methods for control, nor should we neglect other pests of lesser importance.

*Soil Conservation.*—The increased use of soil building and conservation crops will bring up many new pest problems such as grass and pasture insects, forest insects and insect pests of forage crops, which, should be studied.

STUDIES ON RESISTANT VARIETIES.—This is a relatively new field which should not be over emphasized but which should nevertheless be thoroughly explored. This field offers great possibilities for the control of insect pests of field and forage crops where the cost of insecticides is prohibitive. A thorough knowledge of plant breeding genetics is necessary.

LARGE SCALE INSECT CONTROL PROGRAMS.—Experience in grasshopper control programs and with others of a similar nature has shown the need for revising certain control recommendations. Methods of taking samples to determine infestation have to be developed. The annual surveys if carried out, scientifically, offer a wonderful opportunity for broad ecological studies.

INSECT PROBLEMS IN CONNECTION WITH FOOD ENGINEERING.—The South is a great potential producer of fancy vegetables and fruits which can be grown early, frozen, dehydrated, or otherwise processed for shipment to the great industrial centers of the North. There will be problems of pests in the growing crops, demand for blemish-free products and pest problems in connection with food processing.

BIOLOGICAL CONTROL.—The possibility of biological control of certain imported species which are pests of the South should be investigated.

BROADENED SCOPE OF ENTOMOLOGICAL RESEARCH.—Much more information is needed on the biology and control of insect pests of man and animals, ornamentals, forests and structures.

EXPERIMENT STATION RESEARCH IN BEEKEEPING.—There is a need for more information on managing bees for effective pollination of specific crops. Bees must be a part of any program dealing with legume seed production, pasture improvement, soil conservation plantings, fruit production and many basic agricultural programs.

INTER-RELATIONSHIP OF INSECTS.—Fundamental research is needed on the interrelationships of parasitic and predatory insects, and especially the pollinating insects such as the wild bees and honey bees. This is needed so that the evaluation of control measures on both injurious and beneficial insects can be made.

MEDICAL ENTOMOLOGY.—Entomology depart-

ments in state agricultural experiment stations were established primarily for the purpose of investigating agricultural insect problems. As a result, few members of the staffs have taken sufficient interest in insects of medical importance. The problems of medical and veterinary entomology are so closely alike and the need for more research facilities is so great, that we should offer our assistance to the state departments of health and other interested agencies. Many agricultural entomologists now serving in the armed forces will return with experience and training in this field and therefore the state agricultural experiment stations will be staffed with competent medical entomologists.

GRADUATE RESEARCH FELLOWSHIPS.—In state experiment stations, teaching is part of the duties of many members of the research staffs. Thus it is possible to coordinate graduate research with the various experiment station projects. It is of vital importance to train a corps of southern entomologists who know and appreciate southern farm problems. These will be the men who will take our places when we retire. The establishment of graduate fellowships in the experiment stations will (a) give immediate employment to the worthy graduate in entomology, (b) give stimulus for undergraduates to major in entomology because they will have a chance for prospective employment, (c) provide the older staff members with the enthusiasm and ideas of youth (d) provide added personnel to the experiment station and give the necessary assistance on projects to the regular staff, and (e) provide a means for the worthy student to take graduate work in entomology.

OLIVER I. SNAPP — JOHN T. CREIGHTON
ALSTON CLAPP, SR. — H. G. JOHNSTON
CLAY LYLE — C. E. SMITH
WARREN WHITCOMB — F. A. FENTON, *Chairman*
R. C. GAINES

## SUBCOMMITTEE ON COMMERCIAL ENTOMOLOGY

In a recent circular on Post-War problems in entomology. Dr. Annand, Chief of the Bureau of Entomology and Plant Quarantine states that there is an annual loss amounting to 1½ billion dollars caused by insect pests.

From the above staggering figures it should be readily seen that the possibilities for trained entomologists in the Post-War period are unlimited. In our report there may be some overlapping of the report by the Sub-Committee on Employment. However, the two, Commercial Entomology and Employment, are closely related and are of such importance that your sub-committee feels that too much stress cannot be brought forward.

Commercial Entomology can roughly be brought under the following headings: 1—Consulting Entomologists, 2—Pest Control Operators, 3—Public Health Service, 4—Machinery Industry, and 5—Insecticide Industry.

CONSULTING ENTOMOLOGISTS.—There are numerous opportunities in this field, such as large ranches, cotton plantations, fruit and crop producing areas, fruit and vegetable canning industry and the dried processed and frozen food industries.

PEST CONTROL OPERATORS.—This field is almost unlimited. Commercial Entomologists have completely overlooked the possibilities in the smaller cities, of say from 5,000 to 20,000 population. The experience and knowledge that entomologists in the armed forces have gained from pest control operations as practiced in the military service should qualify them for parts of this field.

PUBLIC HEALTH SERVICE.—This branch offers expanding opportunities to commercial entomologists, especially those who have had some training in medical entomology.

MACHINERY INDUSTRY.—The manufacturers of spraying and dusting machinery now recognize that it takes more than engineers to produce sprayers and dusters that will give the proper performance in the field. The commercial crop dusting companies will expand in the Post-War period, and this field offers unlimited potentialities for the commercial entomologist.

INSECTICIDE INDUSTRY.—The possibilities in this field are enormous. This industry is constantly seeking better ways to more effectively use the insecticides that we now have available, and also to develop new and better insecticides. The wide range in this branch of commercial entomology, however, is the sales and service end. One with ordinary training can sell insecticides, but it takes a well trained entomologist to render the type of service that is necessary for a satisfied and profitable customer.

For Commercial Entomology it is quite necessary that one have the proper training in his selected field before venturing out into commercial undertakings. For this reason it is urged that college departments of entomology revise their curricula so as to provide more of the kind of training needed for commercial entomologists. Trained men in the field of entomology are going to be scarce for the next several years as we have very few young men coming along at this time.

There is a matter of vital importance to the Insecticide Industry that has been called to the attention of this Sub-committee. This is a matter that has to do with the various state insecticide laws as they now stand. At this time there is a lot of work being done toward the revision of the present Federal insecticide laws, and it is desired that at some future date that the various State insecticide laws will be modified and revised to a common point.

F. A. FENTON — H. S. ADAIR
CLAY LYLE — HORACE W. LEE, *Chairman*

## SUBCOMMITTEE ON INSECT PEST SURVEY

Insects pest surveys are of two kinds (1) General Surveys and (2) Special Surveys.

GENERAL SURVEYS.—The nature, scope and purpose of general surveys differ greatly. Generally speaking, the various surveys which have been set up by states and by the Bureau of Entomology and Plant Quarantine are in effect the assembling of records of the occurrence and status of insects. Such surveys provide a record of things that have occurred. They also provide an effective way for assembling, recording, and to a certain extent disseminating factual information of continuous value. Summaries of all records made in connection with special surveys should be included as a part of those kept by the general or regular Insect Pest Surveys. These surveys are valuable and should be continued and expanded.

SPECIAL SURVEYS.—Special surveys may now be loosely considered in three groups (a) Surveys to determine the possibility of insect outbreaks, (b) Surveys to obtain current information on economic insects affecting crops and animals, and (c) Surveys of seaports of entry, railroad yards, airports and their environs.

*Surveys to determine the possibility of insect out-*

*breaks.*—In the post-war period it is certain that the public will appreciate warnings of what insect outbreaks it may expect in order that preventive measures may be taken before such outbreaks occur. The insect pest survey can play a very important role in this work. Annual surveys similar to that of the present grasshopper survey should be made to tell us what to expect yearly for each of the more important insects attacking southern crops and animals. Entomologists should keep abreast of the infestations in the several states better than heretofore and this can be done by the enlargement of the work of the insect pest survey. The results of this work can be used to make insecticides available at the right time. Surveys of this kind should be continued, developed and expanded.

*Surveys to obtain current information on economic insects affecting crops and animals.*—Cotton insects, especially boll weevil, bollworm, leafworm and flea hopper; screwworms; pea aphid on peas; Mexican bean beetle; pea weevil; caterpillars on cole crops; potato and bean leafhoppers; velvetbean caterpillar; flea beetles on potatoes and Hessian fly were given special attention in so-called emergency surveys during the season of 1944. One of the most extensive surveys was that of cotton insects. Examinations were made in 25,000 fields for boll weevils, 5,000 fields for flea hoppers, and several thousands for leafworms and other insects. The information thus obtained aided in the orderly distribution of insecticides and in advising cotton growers when and where control was needed. Information obtained on other insects was used in a similar way. Weekly reports were prepared and distributed to the War Food Administration, War Production Board, Insecticide Industry and cooperators on the insect pest survey. The results obtained from such surveys will enable Federal, Experiment Station and Extension Workers to release timely information that will be of value to farmers, insecticide and machinery manufacturers and dealers, and many others interested either directly or indirectly in the production of agricultural crops and animals affected by such pests. Such surveys, to be of value, should be made over a wide area and would involve the services and cooperation of a large number of people. The value of this type of special insect surveys has already been demonstrated. It is highly desirable for this work to be continued, expanded and organized on a permanent basis.

*Surveys of seaports of entry, railroad yards, airports and their environs.*—The expected expansion in international trade following the war and improved facilities for moving commodities between continents will increase the hazard of insect-infested materials reaching this country from foreign nations. Experiences of the past few years emphasize the need for extending and intensifying surveys to detect in the incipient stage newly introduced insect pests. Should an insect of economic importance, or even potential importance, be found every effort should be extended to obtain information on method of introduction, origin, commodity on which it was introduced, time of introduction, and extent of spread. Information thus obtained will provide a basis for preventive or control action. The information will also serve as a guide to industry for the manufacture, stocking and distribution of insecticides.

C. E. SMITH
OLIVER I. SNAPP
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## SUBCOMMITTEE ON MEDICAL ENTOMOLOGY

RESEARCH.—The group believes that the startling developments and accomplishments in the prevention of some of our most important insect-borne diseases during the war period have so brought this field into the limelight that strong support will be forthcoming for further research to develop ways and means of controlling all such diseases in the post war period. It is anticipated that the established Federal and other institutional research agencies which were concerned with these problems prior to the war will be continued and will expand. However, in the past, insects of medical importance have received little attention from State colleges and Experiment Stations and these agencies should be encouraged to undertake investigations and the Office of Experiment Stations might be approached in this connection. Undoubtedly many baffling local problems would be solved by having investigations widely distributed such as would be achieved by the participation of these state agencies. For instance, we have pretty good general knowledge of the ecology of our malaria vectors, however, conditions in widely separated areas frequently still are difficult to evaluate. The field of physiology of insect vectors particularly as related to the development of parasites in the definitive host and the toxicological effects of insecticides is one which needs increased attention. Papers such as that presented by Dr. F. C. Bishop at the recent New York Meetings in which problems concerned in the control of several of our disease vectors were discussed, should be given wide distribution to call attention to these needs.

The benefits to be derived from coordinated research work have been well demonstrated by the rapid progress made in the development of DDT as an insecticide. In this work the Bureau of Entomology and Plant Quarantine, the Army, the Navy, the Public Health Service and the various O.S.R.D. contractors have all maintained contact with one another and exchanged reports and ideas. This group believes that coordination of this type should be fostered and that this association should join with other technical societies in promoting an organization for the coordination of entomological research.

TEACHING.—The group believes that courses in medical entomology should be offered by colleges and universities for the purpose of meeting the needs of the various professions interested in this field. The professional economic entomologist although primarily concerned with crop pests should be given a course in medical entomology so that he will have an appreciation of and some familiarity with the field. A general survey course should be given all physicians and those specializing in tropical medicine should of course have more. The sanitary engineer should be given precise instruction on the biologies of disease-carrying insects, the principles underlying control and the methods, materials, and equipment necessary in the handling of large scale control projects. The student who expects to follow medical entomology as a profession should not only have broad training in the sciences, with a major in entomology, but should follow a more or less prescribed course of training which should include courses in general and systematic entomology, biology, ecology, physiology, toxicology, applied entomology, including practical survey and control work in the field of statistical analysis and report writing. Graduate training in an approved school of

public health to acquire familiarity with the epidemiology of disease and Public Health methods and administration would do much to raise the professional status of the entomologist in public health work. It is believed that some institution should be encouraged to take the lead in working out a course to fit the needs of this field. Some excellent thoughts along this line are contained in a paper presented by Dr. R. L. Usinger at the recent New York Meetings which will appear in an early issue of the JOURNAL.

LARGE SCALE PROJECTS.—It has been rather difficult to summarize the opinions held by the group on the handling of *large scale projects* for the control of insects affecting the health or comfort of man and for this reason purely pest problems are discussed separately from those involving disease control. It will no doubt be accepted by all of us that a fundamental weakness in many control projects in the past, such as those directed against mosquitoes is is that work has been carried on without entomological guidance. The Bureau of Entomology and Plant Quarantine for years has been concerned about this situation and has attempted with some success to get state entomological agencies to become more actively interested in such work. By such participation not only could we have avoided to a large extent many of the unfortunate controversies of the past, such as those involving wildlife, but certainly more effective and economical work would have resulted. It is believed the members of this Association who are State Officials could do much toward improving this condition by taking a more active interest in such work.

The desirability of having qualified entomologists participate in the planning and supervision of projects for the control of insects of medical importance also is not open to question. Here we must recognize that as such projects deal with public health, they are a function of health services and both logically and by established custom in this country, they come under the executive direction of health authorities. On insect control projects prosecuted by the T.V.A. over a period of years, and by such organizations as the Army, Navy, and by the Public Health Service working through the several State Health Departments, the need for entomological work has been recognized. In these organizations control work is directed by a team of specialists consisting of a physician, an engineer, and an entomologist. It is believed that this cooperative approach is logical and unquestionably it has led to conspicuous progress. One result is that entomologist undoubtedly will find openings on the staffs of State Health Departments in the post-war period.

STATUS OF ENTOMOLOGISTS IN PUBLIC HEALTH WORK.—The topic of how to make the status of the entomologist in health work more dignified and secure has been presented to the group for consideration. The feeling of the leader of this group is expressed in the preceding paragraph. That is, the need for entomologists in insect work in connection with health problems is recognized and in the postwar period entomologists will be employed by health agencies. In this field the need will be imperative for cooperative work with other professions and in most cases at least, the degree of recognition accorded the entomologist will depend on the individual, his fitness for the work, and the quality of service he renders.

CREDIT FOR WARTIME INVESTIGATION.—Concerning the question of credit for research work done during the war period, publication of which has been held up for security reasons, it is believed this can only be handled by each paper carrying a date line to indicate when it was prepared. Future authors in giving credit for ideas or findings should be careful to recognize the work having priority, even though its publication date may be later than that of others which perhaps may report similar or more comprehensive data. Editors of journals might give much assistance in handling this vexing problem.

A. D. HESS H. S. ADAIR
JOHN T. CREIGHTON G. H. BRADLEY, *Chairman*

## SUBCOMMITTEE ON VETERINARY ENTOMOLOGY

I don't have a prepared paper on this subject, and I am afraid that if I had one I would have to repeat a lot of what has already been said. Many fine things have been brought out, particularly with reference to training of entomologists and the requirements of that training to meet the requirements of the postwar period.

Lieutenant Colonel Bradley has brought out the fact that before the war we had relatively few trained medical and veterinary entomologists. No one realizes that better than the Army, because it was necessary for the Army and Navy to train many hundreds of men, most of whom will be coming back as veterans, and they will most likely want to continue in this field of work. I believe that at least the majority of them will seek and accept work in medical and veterinary entomology or in some specialty of that branch.

What are we going to do with these entomologists who have had such wonderful experience and training all over the world when they return during the reconstruction period? We should not lose them in this field, and I hope we won't. The only way we can retain them is through planning that will provide attractive and worth-while employment to them in this or other branches of entomology when they return after the cessation of this conflict. I sincerely hope that as a result of sound planning for the postwar period we shall be in position to absorb all the returning veterans who desire to continue entomological work, so that they will not be forced to go into some artificial work—leaf raking, or what have you?—in order to make a living.

We certainly can sponsor enough worth-while projects here in the cotton states alone to absorb all the veterans who cannot be absorbed by Federal and State stations, as was brought out earlier in this program by Dr. Fenton. It is certain that those veterans who will not be able to find desirable work either in Federal or State stations on attractive postwar entomological projects will go into other fields of employment during the reconstruction period and will most likely be lost permanently to some field other than entomology. This I am told will ultimately result in a shortage of trained personnel for the permanent entomological projects which will surely come after the reconstruction period because no or at least only few entomologists are being trained by our colleges and universities during the war. In order to retain them in our profession, we must now begin to plan projects that can absorb all of our returning veterans in this and other branches of entomology and give these men a chance to get into a field of work of their first choice, together with compensation that will attract and hold them, and at the same time do work that will pay real dividends to our cotton states and to our nation.

The projects that I think are most important during the readjustment period are survey, which have already been mentioned, and control and eradication of the more important insect pests here in the South and throughout the nation. The surveys made by our bureau and by the States during the past year or two on cotton insects, grasshoppers, screwworms, etc., demonstrated their value in that they have served admirably in giving us rather accurate advance information on problems that are developing and that we must be ready to meet promptly in order to save our crops and our animals for our war effort.

The screwworm survey in the states west of the Mississippi, which was made from our station in Dallas, determined the spread and abundance of this pest in 16 states during the past year and made it possible to quite accurately estimate the amounts of critical ingredients needed for Smear 62 for controlling this pest. Since these materials are drastically rationed and cannot be released very suddenly, the information we obtained through the survey gives us the advance information as to a pending outbreak and also gives us a chance to get these critical items released, processed, and placed in areas where and when they are needed. As a result of this survey many animals so essential to our war effort were saved. There is certainly plenty need for employment of veterans in surveys of cotton insects, of many other field and orchard pests, and of several serious pests of man and animals.

We certainly also have many control problems that in the aggregate would need more manpower than the war veterans with medical and veterinary entomological training could furnish. One with which we are faced today and which probably affects the Army and our war effort as much as or more than any other single agricultural project pertaining to entomology, is the cattle grub; also lice, flies, and many other important control problems in this and other fields of entomology.

We also have the most urgent need for an insect-eradication project that ever faced the cotton states in the history of cotton—the eradication of the pink bollworm. Another excellent problem of this nature would be the eradication of the screwworm in the Florida area. This is an isolated infestation, and once it is cleaned out it could easily be kept out of the entire southeastern area. I believe this is possible and no more difficult than it was to eradicate the Mediterranean fruit fly from the Florida area.

These are only some of the problems that we should seriously consider in any postwar planning program.

Planning alone, however, will obviously be useless unless we also provide funds in amounts that will be entirely adequate to put our plans into effect immediately after the war and continue them until employment in permanent projects is possible.

I hope that this conference on postwar planning will not result in planning alone but that we will also devise ways and means for securing the necessary funds to put our plans into effect, which is obviously a prerequisite for a sound postwar program in entomology.

E. W. LAAKE, *Chairman*

## SUBCOMMITTEE ON PUBLICATIONS

The Sub-Committee On Publications reports as follows:

1. Although public interest in insect control is being currently stimulated by developments during the war, especially the use of aerosol bombs and the spectacular results with DDT, more publications and publicity of a popular nature are needed to increase public knowledge of the importance of entomology. Efforts along this line should not be limited to official bulletins, circulars or leaflets but should also include news articles, radio programs and other methods. It is suggested that much greater use be made of college agricultural editors, farm papers and farm organization publications.

2. The Sub-Committee on Publications seems to be generally agreed that a textbook on entomology for the South is needed. Insect problems peculiar to this section are usually inadequately treated in texts written for general use and many important pests, for example several destructive pecan insects, are omitted entirely from the texts most widely used in teaching economic entomology. Consideration of publishing costs and the probable college demand for such a text indicate that it would have much better financial prospects if prepared in such form as to serve also as a handbook for county and home demonstration agents, teachers of vocational agriculture and other agricultural workers.

3. The members of the Sub-Committee on Publications are divided as to the need for a new journal for the publication of entomological research in the south. It is asserted by some that southern research papers have been rejected by the JOURNAL OF ECONOMIC ENTOMOLOGY without good reason, while others contend that the JOURNAL OF ECONOMIC ENTOMOLOGY should be developed to the fullest extent possible so as to keep entomologists well-informed on developments in all sections of the country without having to subscribe to a number of publications of the same type. This question should be considered carefully by our entire membership before any action is taken.

4. Recognizing the value of early impressions, it is recommended that efforts be made to include more material on insects in the reading texts used in the elementary grades and in the science texts of our schools. Here is a splendid opportunity to teach in an interesting way the importance of the honeybee, the relation of insects to health and many other entomological subjects. The state boards responsible for the adoption of elementary and high school texts should be approached on the importance and desirability of including this material in the curriculum.

G. H. BRADLEY O. I. SNAPP
JOHN T. CREIGHTON WARREN WHITCOMB, JR.
CLAY LYLE, *Chairman*

## SUBCOMMITTEE ON LEGISLATION

The Subcommittee on Legislation reports as follows:

1. It is recommended that the Southern Plant Board be given the active support of all southern entomologists in its efforts and that those of us engaged in other than regulatory phases of entomology acquaint ourselves with the problems in this field for the two-fold purpose of improving our own services and also in order that we may speak intelligently to the public about quarantines and large scale pest control projects. This is especially important when we consider that appropriations for the support of entomological work of all kinds often depend not on the requests of entomologists but on the amount of public interest in such matters.

2. It seems probable that there will be much greater interest in commercial pest control after the war than existed previously. Therefore, it is recommended that all southern states endeavor to secure uniform laws and regulations for governing the work of pest control operators. It is recognized that the Southern Plant Board has already given consideration to this problem and we urge the Board to continue its efforts along this line.

3. Since regulations of the Federal Food and Drug Administration do not govern the labelling and sale of insecticides wholly within the states in which they are manufactured and are often inadequate to protect buyers in interstate trade, it is recommended that the regulatory agency in each state responsible for official pest control give consideration to securing the adoption of laws and regulations governing this subject. Obviously, such laws and regulations should not be in conflict with the Federal regulations for interstate trade and should be as uniform as possible. To this end it is suggested that the Southern Plant Board appoint a committee to study state and Federal insecticide laws with a view to recommending a model law with uniform provisions in all states.

4. It is recommended that copies of this report be sent to the chairman and the secretary of the Southern Plant Board.

JOHN T. CREIGHTON
F. A. FENTON
C. E. SMITH
H. S. ADAIR
A. D. HEISS
CLAY LYLE, *Chairman*

## THE AUDITING COMMITTEE

The auditing committee has examined the report of the Secretary-Treasurer and finds it correct.

CHARLES LINCOLN
W. W. STANLEY
L. L. ENGLISH, *Chairman*

## THE RESOLUTIONS COMMITTEE

WHEREAS, The Cotton States Entomologists have had a constructive and enjoyable meeting in their nineteenth annual session, we offer the following resolutions:

*Resolved*, That we are deeply indebted to the members of the Local Committee on Arrangements for securing a comfortable meeting place and for providing pleasant entertainment.

*Resolved*, That the Secretary be instructed to write a letter of appreciation to the management of the Hotel Roosevelt and especially that Mr. Roy Bartlett, Convention Manager, be cordially thanked for his sincere efforts in providing a meeting place and other comforts for the members in spite of extremely crowded war-time conditions.

*Be it further resolved*, That the Secretary be instructed to write a letter of appreciation to Mr. B. B. Jones, Agricultural Director of the New Orleans Association of Commerce, for providing the very efficient and courteous assistants who facilitated registration.

We thank Dr. F. L. Thomas and the members of his Committee on Post War Planning for their thought, worry, and constructive suggestions for the good of the profession. Dr. Thomas' unavoidable absence from the meeting is regretted.

*Resolved*, That Mr. D. L. Van Dine, President of the American Association of Economic Entomologists be extended our congratulations for his thought provoking address which brought out the wide value of cooperation in solving insect control problems.

WHEREAS, The members of The Cotton States Branch of the A.A.E.E. recognize the importance of the pink bollworm as the most dangerous threat to the Agricultural economy of the South, and, Whereas, we view with alarm the recent extensive spread of this insect in Texas.

*Therefore be it resolved*, That we endorse the action taken by the Southern Plant Board at its recent meeting at Memphis, Tennessee, commending commissioner J. E. McDonald of Texas and the Bureau of Entomology and Plant Quarantine for the proposed program for suppressing and preventing the further spread of this pest.

Realizing that the future of the cotton industry of America is at stake, we urge the strictest enforcement of the proposed program and pledge our individual and collective efforts in rendering any assistance possible. Be it further resolved, that copies of this resolution be sent to Secretary of Agriculture Wickard, to Commissioner McDonald and to Dr. Annand, Chief of the Bureau of Entomology and Plant Quarantine.

*Resolved*, That the Branch expresses its sorrow on the passing of the following southern entomologists:

E. W. Berger, Florida
Harrison Garman, Kentucky
D. W. Grimes, Mississippi
John C. Hamlin, Mississippi
P. H. Rolfs, Florida
C. E. Sanborn, Oklahoma
Lieut. William Roy West, Mississippi

The Cotton States Branch expresses its appreciation to the several commercial concerns which made it possible by their generous financial assistance to mimeograph the proceedings of the Eighteenth Annual Meeting and War Conference on Entomology. The Secretary of the Branch and his office helpers are due much credit for the tedious work of preparing the many stencils necessary.

*Be it resolved*, That we send greetings to all of our members who are serving our country by special duty, in uniform or not. We deeply appreciate the sacrifices and contributions they are making.

Respectfully submitted,
DAVID DUNNAVON
W. H. MECOM
THEO. L. BISSELL, *Chairman*

## THE EXECUTIVE COMMITTEE

The Executive Committee recommends that the question relative to the holding of a meeting in 1946 be left to the incoming executive committee.

The Executive Committee referred to the Resolutions Committee a special resolution pertaining to Pink Bollworm eradication.

The Committee recommended that a Subcommittee be appointed from The Post-War Planning Committee to consider the establishment of definite standards for professional Entomologists.

The Executive Committee recommends that funds subscribed by Industrial organizations for publication of proceedings be accepted with sincere thanks and appreciation.

The Committee recommends that the Executive Committee, The Post-War Planning Committee, and The Past Chairman meet annually at a central location until Government restrictions on travel are lifted.

The Committee recommends that the Secretary approach the Editor of THE JOURNAL OF ECONOMIC ENTOMOLOGY relative to the publication of proceedings of the Southern War Conference on Entomology.

C. H. ALDEN — JOHN T. CREIGHTON
O. W. ROSEWALL — E. W. LAAKE, *Chairman*

## COOPERATION BETWEEN THE MEMBERS OF INDUSTRY AND ENTOMOLOGISTS

Mr. President, Members of the Agricultural Insecticide and Fungicide Association, and Friends: It is because of your invitation that we appear before you as representatives of Southern entomologists, especially those that constitute the membership of the Cotton States Branch of the American Association of Economic Entomologists. We bring you sincere greetings from our fellow Entomologists. We deeply appreciate the opportunity of meeting with the "Basic Product" producers of the Insecticide and Fungicide Industry. We hope that much good will be derived from our consultations.

It is the opinion of many southern entomologists that there is a definite need for closer integration of activity between entomologists and the members of industry. Accordingly, at our February meeting in the city of New Orleans we appointed a special committee on insecticides. This committee made a report to our membersip which was in turn submitted to our executive committee with specific instructions that concrete action be taken. Subsequently, a petition was formulated and presented to you through your able Executive Secretary, Mr. L. S. Hitchner. The petition follows:

> To the Agricultural Insecticide and Fungicide Association:—Upon recommendation of a special committee on insecticides of the Cotton States Branch of the American Association of Economic Entomologists, the Executive Committee of this organization hereby urges that the Executive Secretary of the Agricultural Insecticide and Fungicide Association bring to the attention of the members of the latter organization the needs of entomological work in the south-southwest, and the part that its members may play in pest control.
>
> Particular attention should be given at this time to such general problems as a more effective distribution system for insecticides, and the need for increased cooperation by members of the insecticide industry in placing representatives of their technical staffs in the several southern and southwestern states to cooperate with State and Federal authorities in field tests.
>
> The members of industry are urged to respond to needs brought about by localized problems when such needs are brought to their attention and the solutions are practicable.

Upon receipt of this petition from the office of your Executive Secretary, many members of industry made what might be termed defensive reply. In these replies you clearly outlined the activities in which you are now engaged in Southern and Southwestern States. These included research fellowships in Southern Institutions of higher learning, cooperative projects with state agricultural groups, the placement of technically trained men in southern regions, research projects with large growers or distributors, the supplying of samples for research purposes, and a conscientious effort to meet regional and local distribution problems.

The south-southwest is a great agricultural region. It produces heavily many crops, such as cattle, hogs, cotton, corn, citrus, deciduous fruits, vegetables, poultry, cereal grains, tobacco, and others. Such a region is worthy of the attention of all who are interested in agricultural stability and advancement. Southern entomologists realize full well the present and past efforts of industry to render worthwhile service. For such contributions we are deeply appreciative, and we unhesitatingly commend you for your conscientious efforts.

The agricultural industry has advanced rapidly during the past fifty years. This advancement has been made possible in great part because of technical research. This research has included entomological research. One branch of entomological research has been that pertaining to the use of insecticides. Yet in this latter field we are only getting started. The technical character of insecticidal research has developed rapidly during the last fifteen years; and such a trend is an indication of progress.

It is encouraging to note that the members of industry have definitely come to appreciate the great value of a technically trained personnel. It behooves professional entomologists to encourage this trend because of the overall value that it will render to entomology and agriculture.

Therefore, it is our thought that in the postwar period you of industry will endeavor to broaden your services, especially in the technical contributions. In your overall planning we urge that due consideration be given problems of the south-southwest. We feel that such an invitation to the members of industry constitutes a high compliment. This is true because it was only a few years ago that many federal and state professional entomologists tended to look with suspicion upon cooperative work with commercial organizations. Now we are trying to join hands in a common effort to advance mankind, and the professional worker has been first to extend the hand of professional unity. This should constitute a milestone in our work.

The members of your organization have asked that we present recommendations concerning methods whereby advancement can be made. We wish to assure you that the points that we shall stress are not criticisms but rather constructive suggestions. These have come to us from numerous field workers in our southern district. Though we who present this discussion concur in most of the recommendations we do not necessarily endorse all of them. However, as representatives of our group we feel obligated to present them to you for your consideration.

DISTRIBUTION PROBLEMS.—*Seasonal Shortages.*—It is likely that the members of the insecticide industry recognize distribution as one of their most perplexing problems. Some of the entomologists in our southern area feel that the members of industry are meeting these problems satisfactorily, while others feel that improvements can be made. It is often true that in certain regions seasonal shortages frequently occur or the supplies are late in arriving. Unless an insecticide is available to the grower when needed it is worthless. It has been suggested that this problem might be solved if manufacturers could establish and maintain large stores of insecticides in high crop

production regions in order that supplies would be available to local dealers on short notice. This would avoid forced production of insecticides at undesirable times which usually creates a sharp rise in price under heavy demand conditions.

SMALL PACKAGE PROBLEM.—The small package problem continues, including the unreasonable cost of such packages. In some areas the majority of insecticides sold are in small packages and a constant effort should be made to meet demands in all small cities and towns. Government and State workers with the cooperation of Industry might solve this problem by encouraging farmers and other consumers to organize buying clubs or cooperatives. The manufacturer could then reach the consumer through fewer customers and larger packages.

TRAINING OF DEALERS.—Distribution could be effectively improved if dealers in insecticides were better trained. Their lack of knowledge makes them quite hesitant concerning the purchase of new materials, and the purchase of sufficient quantities of insecticides to take care of heavy seasonal populations (outbreaks) of a given economic species.

COOPERATIVE RESEARCH.—Cooperative research in entomology can be made valuable to all concerned. This type of close affiliation between members of the insecticide industry and state and federal entomologists is desirable. These contacts should be more frequent than they are at present. Such cooperative endeavors should have as their prime objective the establishment of scientific principles with the testing or comparison of brands relegated to a place of secondary importance.

*Preliminary Tests.*—It seems extremely important that industry should have their professional entomologists do the major part of all preliminary testing unless it is done on a fellowship basis. Field testing of released materials by federal and state entomologists should be subsequent to such thorough preliminary tests.

*Manufacturers Knowledge of Problems.*—The first approach of any manufacturer in a state should be a conscientious effort to become thoroughly familiar with all insect problems of the state. Cooperative research should take into consideration the various conditions that exist within a state due to climatic and soil conditions as well as other factors.

In seeking knowledge concerning insect problems in a state the members of industry should carefully counsel with entomologists and not depend upon the opinions of self-appointed authorities in this field Yes, each year the members of industry will find that they need additional expert entomological advice. We expect you to lean heavily upon members of our profession. It is noteworthy that you are appointing more entomologists to your technical staffs. Whenever you deal with the complex problems that insects present you will need professional entomologists. If you find that in certain areas and states you do not need the services of a full time entomologist, you might give consideration then to the appointment of entomologists on a consultant basis. Smaller industries might find such an arrangement quite worthwhile.

RESEARCH FELLOWSHIPS.—*Economic Research.*—The most economic method of obtaining research data is through the establishment of research fellowships, and at the same time it aids in the professional training of young men who will eventually take their proper places in the profession.

Industrial research fellowships in the field of entomology have frequently resulted in definite scientific contributions. The relationship between institutional leaders and representatives of industry have generally been considered cordial.

In the postwar period the number of such fellowships will doubtless be greatly increased. In the south many insect problems could be solved through that medium; problems which full time personnel can not attack because of the limited appropriations involved.

*Remuneration and Travel Funds.*—Permit us to suggest methods whereby such fellowship arrangements might be improved. It might be well to consider an increase in the remuneration of the research fellowship and in the travel fund for supervision. The former will enable supervisory committees to select more capable men, while the latter will provide for closer supervision. Research fellowships should frequently be of a character that will permit the research workers to study problems under large scale field conditions as well as small plot or laboratory conditions. It would seem advisable to place stress upon the practical aspects of our many problems.

*Outright Grants.*—An idealistic arrangement between the members of the insecticide industry and southern institutions would be outright grants from industry for fellowships without administration of operational limitations relative to the problems studied. Whenever an agreement is made relative to discoveries provision should be made for royalties to be deposited in a research fund which would perpetuate entomological research at small cost to industry.

*Purchase of Equipment.*—The members of industry might logically consider the desirability of making direct contributions for the purchase of desirable equipment for some departments; and even the establishment of completely equipped laboratories. This would possibly constitute a very economical method of conducting toxicity studies under the guiding hand of technically trained entomologists.

*Training of Young Men.*—Such arrangements as the aforementioned would facilitate the training of young men for employment by industry. Industry might go farther and consider the full time employment of graduate and undergraduate students during summer periods. This would contribute to their training while enabling administrative officers of industry to study their qualities from a permanent employment angle.

EXTENSION ENTOMOLOGY.—*Broader Use of Products—Cooperation.*—In the final analysis the manufacturer is primarily interested in the broader use of his product. Extension entomologists and other extension workers in great part hold the key to this problem. Therefore, there should be close and cordial cooperation between the two groups. Such a cooperative spirit can only exist when there is complete forthrightness and fairness. The extension worker must of necessity know the chemical nature of any insecticide that he is expected to recommend or endorse. Professional confidence on both sides is essential.

*Insecticide for Field Demonstrations.*—The members of industry usually seem willing to supply quantities of insecticides for field demonstrations by extension workers. In this regard, caution must be used to guard against favoritism, and requests for too much free material.

*Extension Workers Obligation.*—Extension workers

must realize that it is their obligation to keep research entomologists informed concerning performance of the control measures that are recommended.

*State Recommendations.*—The members of industry should make a concerted effort to follow the recommendations made by state workers and not make blanket recommendations for entire regions. The solution to many such problems will be found in more frequent meetings between research and extension workers and the members of industry.

*Industrial Extension Entomologists.*—One of the great weaknesses in the south today is the fact that some states have good representation by the members of industry, but do not have extension entomologists; while other states have extension entomologists but industry has not deemed it advisable to assign entomological representatives to such areas. It is quite possible that the members of industry may find it profitable in the postwar period to employ technically trained but practical minded extension entomologists for service in some of the southern states.

In conclusion we desire to commend the members of the Agricultural Insecticide and Fungicide Association for their many worthwhile activities and especially for the publication—AIF News. We find this publication invaluable in keeping us well posted on current questions concerning insecticides and fungicides. The news items are also stimulating.

We look forward with pleasure to our future contacts with members of your organization.

Approved by the Executive Committee of the Cotton States Branch of The American Association of Economic Entomologists.

E. W. LAAKE
C. H. ALDEN
JOHN T. CREIGHTON

Presented at the annual open meeting of The Agricultural Insecticide and Fungicide Association held at Spring Lake, New Jersey, September 6 to 8, 1944, and summarized at The Second Southern War Conference on Entomology at New Orleans, Louisiana.

## REPORT OF THE NOMINATING COMMITTEE

The Nominations Committee recommended the following officers:

C. E. SMITH, Baton Rouge, Louisiana, *Chairman* 1945–46.

THEO. L. BISSELL, Experiment, Georgia, *Vice-Chairman* 1945–46

JOHN T. CREIGHTON, Gainesville, Florida, *Secretary-Treasurer*, 1945–48.

These officers were duly elected. The New Chairman was escorted to the place of honor by past chairmen. He expressed appreciation for the honor bestowed upon him and asked for the cooperation of the entire membership.

Final adjournment was proclaimed shortly thereafter.

JOHN T. CREIGHTON
*Secretary-Treasurer*

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## DR. J. LINSLEY GRESSITT

Lt. (j/g) J. Linsley Gressitt writes that he has just been released from the Navy where he served as a member of Medical Research Unit No. 2 in Guam, and on the Staff, Commander of the U.S. Fifth Fleet in the Philippines, Okinawa and in Japan since the surrender.

Lt. Gressitt remained more or less anonymous in the Navy because he had been interned by the Japanese for the first half of the war while his father was in the hands of the Japanese throughout the war.

On Okinawa Lt. Gressitt was aide to the Medical Officer of the fleet and in the Philippines he studied flies of medical importance, other than mosquitoes.

Dr. Gressitt's continued interest is in China where he has had much entomological experience and ranks high as an authority on Chinese Entomology, especially its economic phases.

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